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REMOVAL OF SIMULATED FALLOUT FROM PAVEMENTS BY CONVENTIONAL STREET FLUSHERS

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ADMINISTRATIVE INFORMATION

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ABSTRACT

A conventional motorized street flusher was evaluated as a suitable decontamination tool to be used in the operational recovery of extensive paved areas contaminated with fallout from a land-surface nuclear detonation. The selection of fallout parameters such as particle size and initial mass levels was based on a theoretical fallout model.

The flusher nozzle orientation was adjusted for maximum decontamination effectiveness. This adjustment can be applied to any flusher to be used for similar purposes. Using a fixed set of flusher adjustments and constant-size test area, the effects of 4 particle size ranges, 3 mass levels, and 2 types of surfaces on removal effectiveness were determined.

The least effective removal by flushing (2.2 g/ft^2 residual mass) for a given expenditure of effort was obtained at high initial mass loadings (100 to 600 g/ft^2) on asphalt surface using small particles (44-88 μ and 88-177 μ). The best removal effectiveness by flushing (0.06 g/ft^2 residual mass) for the same expenditure of effort was obtained using low initial mass loading (20 g/ft^2) on concrete surface with 350 to 700 μ particle sizes.

A majority of the tests conducted were in agreement with previously developed theoretical equations describing decontamination in terms of residual mass as a function of expended effort.

SUMMARY

The Problem

Reclamation of extensive paved areas contaminated with fallout from a land-surface nuclear detonation may be required. The decontamination procedure used, of the several available, depends on the particular environmental and contamination conditions in conjunction with the capabilities of the procedures. In regions where an adequate water supply is available, wet decontamination such as motorized flushing may be the primary procedure; or it may be used in combination with dry procedures as a final clean-up method. Therefore motorized flushing should be evaluated under predicted fallout conditions of mass loadings, particle sizes, and surface roughness. Variation in machine parameters such as water pressure, nozzle orientation, and speed should be tested to determine the conditions of optimum effectiveness for decontamination purposes.

Findings

Using radionuclide-traced sand to simulate dry fallout from a nuclear weapon detonation on a land surface, motorized flushing effectiveness data were obtained for one optimum combination of machine and operational parameters. This optimum combination was tested under several environmental conditions including mass levels of 20, 100, and 600 g/ft^2, and particle size ranges of 44-88 μ, 88-177 μ, 177-350 μ and 350-700 μ, on asphalt and concrete surfaces.

The effectiveness achieved depended upon the critical adjustment of flusher parameters which included nozzle orientation and nozzle pattern adjustments. The highest degree of effectiveness achieved was with low mass loadings (20 g/ft^2) on concrete surface using large particle sizes (350-700 μ and 177-350 μ). The observed rate of removal as well as final residual mass obtainable were a function of mass loading and particle size.

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REMOVAL EFFECTIVENESS OF SIMULATED DRY FALLOUT FROM PAVED AREAS BY CONVENTIONAL MOTORIZED STREET FLUSHER

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SPECIAL SUMMARY (Pages A-D, inclusive; for OCD use as detached document)

PURPOSE AND OBJECTIVES

Recovery from a land-surface nuclear weapon detonation requires that proper countermeasures be used during the various phases of radiological recovery activity. In regions where enough water is available for large-scale decontamination, motorized flushing could be applicable to cleaning extensive paved areas such as streets. To determine the decontamination capability of a commercially available motorized street flusher, one was tested under controlled environments of simulated fallout using optimum machine adjustments.

Previous evaluation of wet decontamination procedures and the recently developed concepts of fallout environment simulation indicated that the evaluation tests attempt to:

a. Verify previously established wet method contamination parameter relationships, or establish new relationships.

b. Determine specifically and separately the effects of the following on decontamination effectiveness:

(1) Deposited initial mass levels.
(2) Particle size.
(3) Surface roughness.

A study was made of the removal effectiveness of simulated fallout from asphalt and concrete surfaces by a motorized street flusher, and the following objectives were met;

a. Measure and select the best operative conditions for available motorized street flushers, including improvements in equipment design and operational procedures.

b. Determine the decontamination effectiveness of motorized street flushers performing at optimum operating conditions of nozzle orientation, water pressure, and forward speed, in the removal of fallout simulant of various particle sizes and mass loadings from paved surfaces of asphalt and concrete.

SCOPE

Optimum operative conditions, and adjustments of nozzle orientation and water pressure, were determined by small-scale preliminary tests. Then 22 full-scale tests were conducted at one intermediate speed (6 mph) and the best operational procedure (involving flushing sequence and nozzle arrangement) to determine the effect of surface roughness and fallout parameters of mass loading and particle size on decontamination effectiveness. The extent to which these effects were investigated by the 22 tests is indicated in the table below.

Initial Mass (g/ft^2)	Surface Type*	Particle Size Range** (μ)			
		44-88	88-177	177-350	350-700
20	A	X	X	XX	X
20	C	X	X	XX	X
100	A	X	X	XX	X
100	C	X	X	XX	X
600	A		X		
600	C		X		

*A - Asphalt
 C - Concrete
**X - Indicates one test run.

FINDINGS

Three types of factor influence flusher cleaning effectiveness: (a) environmental conditions, such as surface type and roughness, contaminant particle size, and mass loading; (b) machine characteristics, such as nozzle design and configuration, stream pattern, and water pressure; (c) operational or procedural qualities, such as flushing sequence, forward speed, and directional control.

a. For all environmental conditions, removal effectiveness is maximum when both forward nozzles are orientated such that the two jet stream planes intersect the surface in one straight line, which is canted at 55° with the direction of travel. The dip angle of the left front nozzle is 10° and that of the right front nozzle is 22°, and the dihedral angles are zero.

b. For a given amount of effort the rate of removal as well as lowest final residual mass obtainable was a direct function of particle size and an inverse function of mass loading.

c. The highest degree of effectiveness was achieved on concrete surfaces, at low mass loadings (20 g/ft^2), and with the large particle size range (350-700).

d. The previously developed theoretical cleaning equation (described below) fit the data for 13 out of 22 of the tests.

CONCLUSIONS

The conclusions suggested by the test results are as follows:

a. The adjustments and orientation of the nozzles described in Section 2.2 of this report can be applied beneficially to most commercial street flushers.

b. Under conditions similar to those tested, fallout parameters and surface type will probably influence flushing effectiveness in the following way:

(1) High initial mass levels will be harder to remove than low initial mass levels.
(2) Small particle sizes will be more difficult to remove than large particle sizes.
(3) Rough asphalt surfaces will retain a greater residual mass than screeded concrete surfaces.

c. Motorized flushing is an effective decontamination procedure for recovery of extensive paved areas, if the following problems are recognized and overcome: (1) possible water shortage; (2) insufficient number of flushers; (3) excessive accumulation of flushed material due to high initial mass levels, or the accelerated build-up of flushed material in an extensive area having a low initial mass level; and (4) the safe handling and ultimate disposal of the flushed material.

d. The performance of motorized street flushers can be reasonably described by the flushing equation:

$$M = M^* + (M_o - M^*)\, e^{-3K_o E^{1/3}}$$

where M is the residual mass (g/ft^2) after finite effort expenditure E
M^* is the residual mass (g/ft^2) at an infinite effort level
M_o is the initial mass level (g/ft^2)
K_o is the proportionality constant expressing removal rate
E is effort expended (equipment min/10^4 ft^2)
$e^{-3K_oE^{1/3}}$ is the fraction of removable mass remaining after expending effort, E.

RECOMMENDATIONS:

Since the series of tests conducted represents a very limited effort, the following investigations are recommended:

a. Further tests should be conducted to explore possible improvements in flusher design and operating techniques.

b. Investigations should be made to determine whether a combination method (such as sweeping followed by flushing) might show improved performance on higher mass loadings.

c. Additional tests should be made to determine the effects of increased speed and nozzle pressure upon flusher performance.

d. Since the present test data did not completely substantiate the cleaning equation, further investigations should be made to either verify the equation or develop a new one.

e. Large-scale tests should be performed on streets extending a block or more to obtain planning information, including turn-around losses and RN_2 dose factors.

FIGURES (Cont'd)

CHAPTER 1

INTRODUCTION

After the shelter phase, recovery from a land-surface nuclear weapon detonation requires that proper countermeasures be used during the various phases of radiological recovery activity. Decontamination is the major countermeasure to be used during the operational recovery phase which occurs after the emergency phase of shelter protection and before the long-term recovery phase of contamination control.

The decontamination procedure to be used in each contaminating situation depends upon the fallout characteristics, the decontamination materials and equipment available, and the nature of the surfaces to be decontaminated. In a land-surface detonation the radioactivity is associated with the particulate fallout material in such a way that the prime criteria for decontamination are mass removal and disposal. In regions where enough water is available for large-scale decontamination, motor flushing could be applicable to cleaning extensive paved areas such as streets.

The manner in which most motorized flushers are used is not suitable for decontamination. The usual dust-settling spray techniques are not compatible with high-pressure water transport of deposited fallout particulate. To determine the decontamination capability of a commercially available motorized flusher, one was tested under controlled environments of simulated fallout using optimum machine adjustments which gave the best performance in preliminary small-scale tests.

1.1 BACKGROUND AND HISTORY

The usefulness of motorized flushers for decontamination was recognized as early as 1952 when operations at San Bruno,[1] using radiotracer Y^{90} in a contaminant of seawater slurry at an initial mass of 78.5 g/ft^2, required a flushing flow rate of 0.5 gal/ft to reduce the initial mass to 3 g/ft^2.

At Operation Stoneman I[2] in 1956 conventional motorized flushing was used on dry simulated fallout at a deposited mass level of 250 g/ft^2. Water consumption rates of 0.5 gal/ft^2 were used and produced 2 % residual mass levels.

At Operation Stoneman II[3] in 1958, conventional and improvised motorized flushing were tested using dry fallout simulant at 10, 33, and 100 g/ft^2 initial deposit mass levels. Using improved nozzle adjustments and higher water pressures than before, the water consumption rates were 0.12 to 0.16 gal/ft^2 with a residual mass level from 1 to 6 % of the initial mass level.

Motorized flushing at Camp Parks in 1959 and 1960 during Target Complex Experiments I and II[4] and III[5] was an integral part of the whole recovery sequence, so that the individual effectiveness of the flusher was not determined.

Recently developed concepts of fallout environment show a relationship between deposited initial mass and particle size range.[6] These model relationships have permitted the systematic selection of simulated fallout environments for the present evaluation of a motorized street flusher for decontamination. Previous evaluations of wet decontamination procedures[3,4,5] and the recently developed concepts of fallout environment simulation[6] indicate that the present tests should attempt the following: (a) to verify previously established wet method decontamination parameter relationships or establish new relationships; and (b) to determine specifically and separately the effects of deposited mass level, particle size, and surface roughness on decontamination effectiveness.

1.2 OBJECTIVES

The present series of motorized flusher evaluation tests was intended to:

a. Measure and select the best operative conditions for available motorized street flushers, including design improvements in equipment and operational procedures.

b. Determine the decontamination effectiveness of street flushers performing at optimum operating conditions of nozzle orientation, water pressure, and forward speed in the removal of fallout simulant of various particle sizes and mass loading from paved surfaces of asphalt and concrete.

1.3 APPROACH

The broad scope of the objectives implies a large number of tests to cover all combinations of parameters for flusher and expected fallout environment. To reduce the number of tests, a fixed optimum combination of machine parameters was first established. This combination was then applied to a series of different fallout environments to determine the effect of several environmental factors in greater detail.

Optimum machine operating conditions were established as follows:

a. A single intermediate forward speed of 6 mph was selected and maintained throughout the test series. This speed provides adequate maneuvering capability and is representative of flusher operation for a majority of applications.

b. Water pressure was maintained near maximum to impart as much kinetic energy as possible to the particulate on the contaminated surface.

c. Previous experience and a series of preliminary tests were used to establish the best nozzle attitude settings, location on flusher, and use of individual or combinations of nozzles.

Several flushing techniques and sequences of techniques were tried on the test area before a uniform procedure was adopted which would permit an accurate determination of the effect of environmental factors.

Environmental factor effects were then determined as follows:

a. A special test area was constructed for environment control to permit measurement of decontamination effectiveness as reflected by residual mass, using either a material weight balance technique or a radionuclide-traced fallout simulant.

b. Equal areas of asphalt and concrete were used to determine the effects of surface roughness. Surface roughness of pavements can be indicated only in a qualitative manner on a relative basis, since there is no standardized method of comparing two surfaces in different locations. For these tests, only one concrete area and one asphalt area was used to provide an unchanging surface parameter while mass level and particle size effects were determined.

c. Four available particle size ranges were used at three initial mass levels in conformance with recently developed concepts of fallout environment.[6] Table 1.1 shows the estimated range of fallout environments

TABLE 1.1

Estimated Range of Fallout Environment Parameters

Particle Size Range (μ)	Weapon Yield (KT)	Standard Intensity (r/hr at 1 hr)	Initial Mass (g/ft^2)	Downwind Distance from Detonation Point (mi)
44- 88	1-10^5	1- 6,400	0.3-192	23 -180
88-177	1-10^5	48-29,500	1.4-885	8.3-120
177-350	1-10^5	110-24,000	3.3-720	4.0- 87
350-700	1-10^5	154-22,000	4.6-660	2.2- 77

simulated. Corresponding to each of the size ranges used are the other environmental factors: estimated ranges of weapon yield, standard intensity, initial mass level, and downwind distances. The three specific mass levels (20, 100 and 600 g/ft^2) chosen for the tests were within the estimated ranges predicted by the fallout model. These levels were held constant so that particle size effects could be determined.

The theoretical implications of test results were analyzed as follows:

An IBM-704 computer was used to correlate test data with the previously developed cleaning equation. The equation[3] in the form

$$M = M^* + (M_o - M^*)\ e^{-3K_o\ E^{1/3}}$$

was solved for 13 of the 22 tests conducted.* The results are presented in Section 3.5 showing the estimates of the equation's coefficients 3 K_o and M^*.

1.4 SCOPE

The limited funds available for this project and the effort involved in getting each data point required a judicious expenditure of experimental

*Terms of the equation are defined in Section 3.5.

TABLE 1.2

Scope of Test Conditions

Mass Loading (g/ft^2)	Particle Size (μ)	Surface Type
20	44- 88	A
20	44- 88	C
20	88-177	A
20	88-177	C
20	177-350	A
20	177-350	C
20	350-700	A
20	350-700	C
100	44- 88	A
100	44- 88	C
100	88-177	A
100	88-177	C
100	177-350	A
100	177-350	C
100	350-700	A
100	350-700	C
600	88-177	A
600	88-177	C

A = Asphalt
C = Concrete

effort. Seventy preliminary small-scale tests were run to determine optimum machine adjustments of nozzle orientation and water pressure at one intermediate speed and the best operational procedure (involving flushing sequence on the test area and nozzle usage combinations). Then 22 tests were run to determine the effect of fallout environment parameters of mass level, particle size, and surface roughness on decontamination effectiveness. Eighteen separate test conditions were met as shown in Table 1.2 Four of the 22 tests were replications.

CHAPTER 2

TEST PROCEDURES AND MEASUREMENTS

Decontamination of paved areas covered with particulate fallout from a land surface burst involves the removal of radioactive particles from the surface, and safe disposal of the material. The use of water as a decontaminating agent can best be effected by the use of a motorized flusher which washes the contaminant into a ditch or catch basin or to some collection point where other methods must be used for ultimate disposal. It is therefore of interest and necessary to study the operating characteristics of motorized flushers to optimize their use for wet decontamination.

Three types of factors influence flusher cleaning effectiveness. The first type includes environmental conditions such as weapon detonation conditions, surface type and roughness, and contaminant particle size and initial mass level. The second type includes machine characteristics such as forward speed, nozzle design and configuration, and water pressure. The third type includes operational or procedural factors such as contaminant buildup with distance covered, contaminant containment within the operation area, and ultimate accumulation and disposal of the contaminant.

The tenacity of adherence of dry solid particulate fallout to a paved surface depends upon such factors as the force of gravity, particle size, and surface roughness. Since flushing consists of physically moving material across the surface to a collection or disposal point, these factors have an important effect upon the decontamination effectiveness when applied.

No consideration is given to leaching and exchange of soluble radionuclides to the surface, since the fallout simulant used is specially processed to minimize errors introduced in the radiation measurements from this source.

2.1 TEST SITE

A special test area was constructed to provide rigid environmental control during the tests. A section 170 ft long on an existing 32-ft wide asphalt street at Camp Parks, California, was used as a foundation for the test area shown in Figs. 2.1 and 2.10. New 8-in. concrete curbs with 18-in. wide gutter aprons were constructed for lengths of 140 ft on both sides of the street. One half of the street (16 x 140 ft) was paved with concrete, finished to simulate freeway pavement, and the other half was resurfaced with asphalt up to the level of the concrete. A system with grid lines was painted to help with measurement and identification of areas during the tests.

A system of drainage trenches was built around the periphery of the newly paved areas, open along the curbs and covered with steel gratings across the street to permit unimpeded vehicular traffic. Four sumps associated with catch basin gratings in the curb apron were used for accumulation and recovery of simulated fallout material flushed from the test area. Material could be flushed from the test surface for recovery into 50-gal drums suspended in each sump, while the excess water drained to the low point of the system (sump #2) where it was pumped to a safe disposal area. Four-foot-high splash boards along the back of the side trenches controlled the material that splashed over the curb.

The original intent of this test area was to provide sufficient control of the fallout simulant so that the material flushed from the surface could be collected and weighed to determine the effectiveness on a weight basis. However, the accuracy of the material balance was of the order of 10 %, which was unsatisfactory for the residual mass levels achieved (about 1 %) in many cases. Also involved is the common source of inaccuracy in subtracting two nearly equal values (initial mass and mass removed).

When the radionuclide-tagging method of measuring residual mass on the test surface is used, the trenches provide a shielded location for flushed material so an accurate measurement could be made. The accumulation of the contaminant in the drainage system also provided radiation shielding for test personnel during cleanup after each test. Use of the drainage system may not simulate operation in a real situation, but it does permit measurement of the effect of mass level, particle size, and surface roughness on decontamination effectiveness by eliminating some of the problems experienced in previous tests.

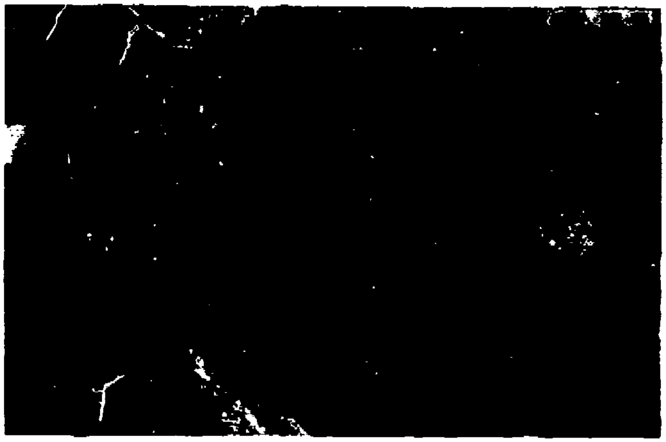

Fig. 2.1 Special Test Area for Evaluation of Wet Decontamination Procedure.

The test area was large enough to permit taking sufficient radiation readings to establish average values and to simulate a possible operational procedure for the flusher, yet it was small enough to allow carrying out the tests with a moderate amount of materials and manpower, and obtain reasonable values for water consumption per square foot.

2.2 DESCRIPTION AND ADJUSTMENT OF FLUSHER

The flusher used for the tests was a World War II vintage machine which was up-dated with a higher-capacity pump and a set of new nozzles. The features it had in common with most flushers were: (a) a large-capacity water storage tank mounted on a truck chassis and filled by hose from a fire hydrant; (b) an auxiliary engine driving a water pump to provide the required water pressure and flow for the nozzles; and (c) several nozzles with orientation adjustments and whose operation is independently controlled by the operator. Detailed specification of the machine is given in Appendix D.

Pretest speed calibration runs with the flusher resulted in the performance curves shown in Fig. 2.2. Low- and high-range rear axle settings could be used with each of the 5 forward gears. The 6-mph forward speed with the truck engine operating at 1350 rpm (transmission gear L3) was used. An engine tachometer mounted in the cab enabled the driver to maintain the exact rpm.

The design of a standard flusher nozzle was studied to determine its applicability to decontamination where high pressure and velocity with a low flow rate is desirable. Although the nozzle orifice gap could be decreased to achieve desirable results, it was decided to use newly purchased and unaltered standard nozzles at the two front nozzle positions so that the test results would be representative of commercially available and extensively used equipment. The use of a standard nozzle at the right rear position was not desirable because it provided neither sufficient pressure nor a confined stream pattern. Therefore a specially designed* nozzle was scaled up and adapted for use on the flusher. This nozzle produced a 30° included angle of spray that was a compromise between the 70° included angle of the standard flusher nozzle and the narrow stream of a standard fire nozzle. The left rear nozzle was a standard flusher nozzle used only to wash down the test area splash boards (Fig. 2.12). The flow rate vs pressure performance of each nozzle is shown in Fig. 2.3.

*By W. L. Owen of this laboratory.

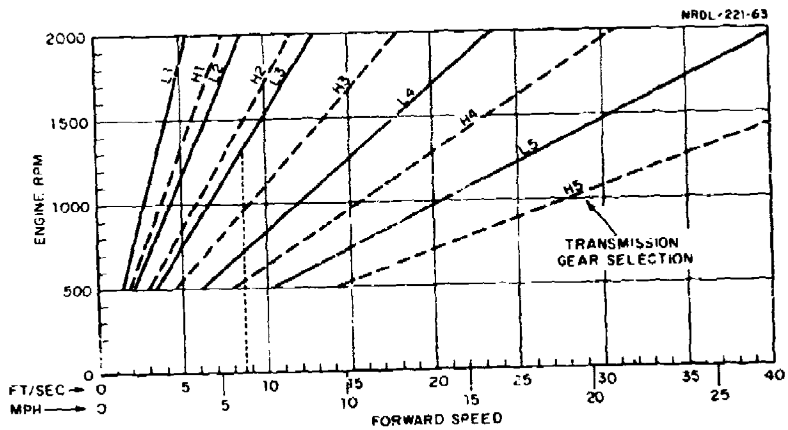

Fig. 2.2 Street Flusher Performance

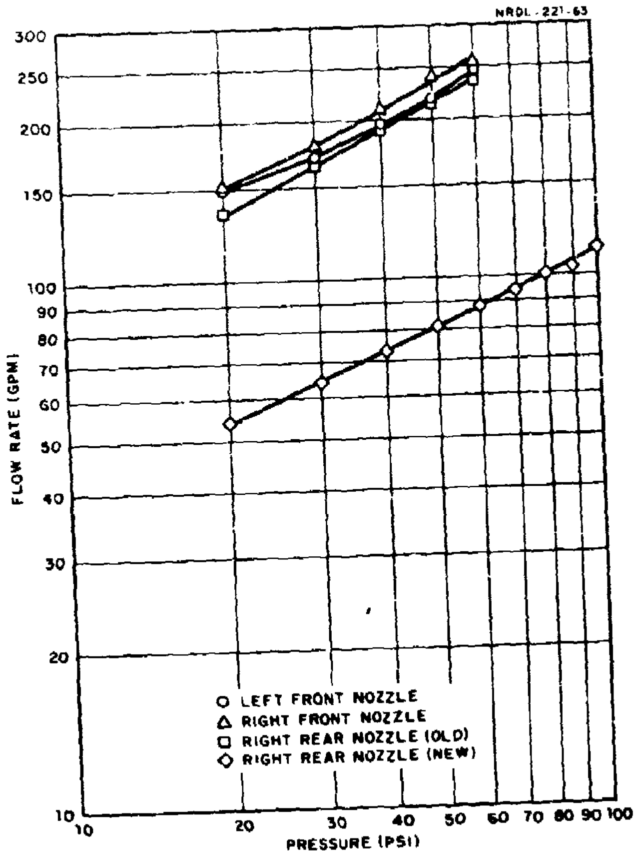

Fig. 2.3 Calibration of Nozzle Flow Rates at Pressures of Interest

An infinite number of combinations of nozzle geometries and orientations was possible. Therefore a systematic approach to the selection of the one combination used for the tests was required. Previous flusher evaluations indicated that good results were obtained when the spray planes of the two front nozzles intersected the pavement in a single straight line to produce a cleaning action similar to that of a road grader with its blade at an angle to the direction of travel (Figs. 2.4, 2.5, 2.6). To increase the path width flushed, the left front nozzle was moved to the extreme left of the machine where it cleaned the full tread width of the left tires and prevented tracking of contaminant to clean areas. The procedure for nozzle orientation, applicable to any flusher, can be explained by reference to Fig. 2.4. To achieve a road grader blade action, all components of the spray velocity should be directed to the right or toward the gutter of the street. Therefore the two front nozzles were oriented in azimuth so that the left edges of the spray were parallel to the direction of travel. The dip angle at which each of the spray planes is depressed from the horizontal was adjusted so that both spray planes intersected the pavement in the same straight line at 55° with the direction of travel. The 10° dip angle of the left nozzle was found to be most effective from preliminary small-scale tests, and the 22° dip angle of the right nozzle was required to continue the straight line of impact. No nozzle rotation around the centerline of the spray was considered and the nozzles were always set so that the dihedral angles were essentially zero. Table 2.1 shows optimum nozzle settings and pressures determined by preliminary tests. Consistent nozzle orientation was maintained by using the bar and protractor arrangement shown in Fig. 2.5. To reduce the number of variables to be evaluated, a series of preliminary tests was used to determine what appeared to be the best procedural method of flushing contaminant from the two paved test surfaces. The procedure adopted is described later under Section 2.6 and was repeated in as nearly identical manner as possible for all tests.

2.3 PRODUCTION OF FALLOUT SIMULANT

Bulk carrier material for fallout simulant was formulated from two types of commercial sand having physical and chemical properties similar to those of real fallout. Each type was readily available and could be easily processed to simulate the fallout environments described in Table 1.1. The medium-to-large particle size fallout simulant was obtained from #60 mesh Del Monte sand, a smooth, weathered, river bottom material in the size range 105-700 μ. The smaller particle size range simulants were sieved from 44-177 μ Wedron river bottom sand.

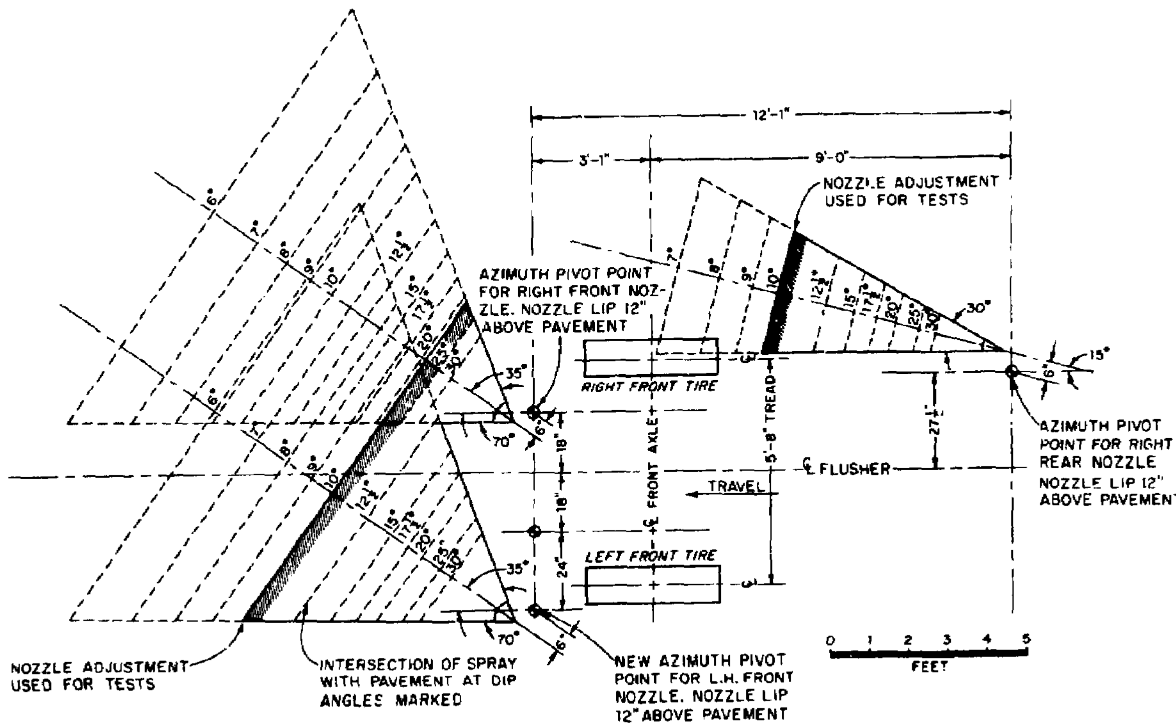

Fig. 2.4 Street Flusher Nozzle Geometry

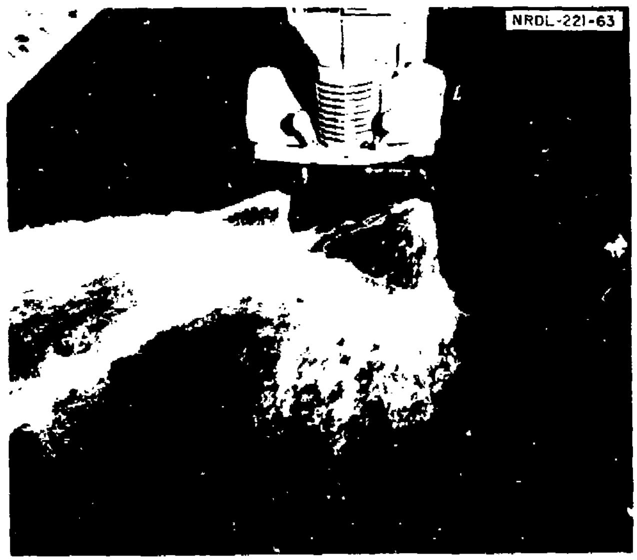

Fig. 2.5 Front Nozzle Operation Showing Protractor Bar Used to Obtain Proper Nozzle Orientation. Protractor points occur every 10 degrees.

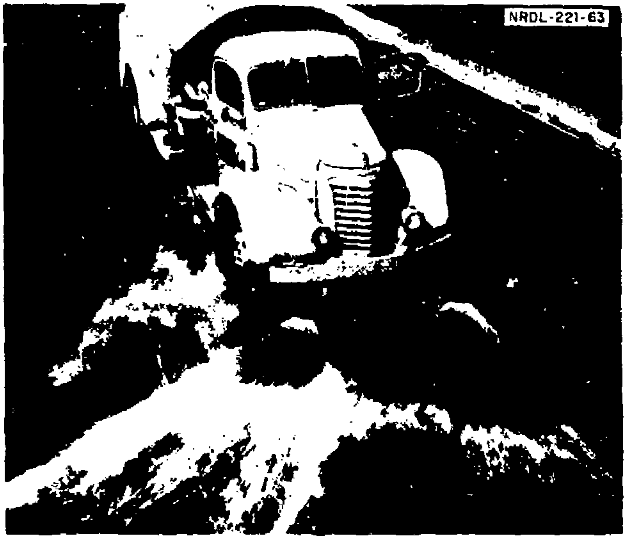

Fig. 2.6 Three-nozzle Operation at Settings Used for Evaluation Tests.

TABLE 2.1

Optimum Nozzle Settings and Pressures

Nozzle:	Left Front	Right Front	Right Rear
Dip Angle:	10^{o}	22^{o}	10^{o}
Azimuth Angle:	35^{o}	35^{o}	15^{o}
	Pressure (psi)		
1st Pass:	40	40	-
2nd Pass:	35	35	60
3rd Pass:	-	35	60

Note: Forward speed was constant for all passes at 6 mph.

The radionuclide La^{140} used to tag the bulk carrier material was selected for several reasons. Its energetic gamma rays minimized the shelf-shielding effects of the simulant at high initial mass levels, making the radiation measurements more nearly proportional to the mass present if the specific activity (μc/g) was uniform. Radioactive decay by a 40.2-hr half-life reduced the residual radiation levels to background in a few days and permitted reuse of the test area. Existing facilities for the preparation and handling of the La^{140} developed for other reclamation projects[4,5] were available at Camp Parks.

Coating the tagged bulk carrier with sodium silicate and baking for 1 hr at 2000°F formed a waterproof glaze which assured that the activity remained fixed to the bulk carrier so that it was not transferred to the test surface.

2.4 DISPERSAL OF FALLOUT SIMULANT

One of the criteria imposed upon the test conditions was a uniformly dispersed initial mass of fallout simulant on the test area. The mass loading depended upon the fallout environment being simulated.

Uniform dispersal was achieved by using a calibrated, hand-operated garden spreader (Fig. 2.7; O. M. Scott and Sons, Marysville, Ohio). The average initial mass level was determined by weighing the spreaders before dispersal and again afterwards. The uniformity of dispersal was visually better than that achieved previously with a dump truck.

2.5 MEASUREMENT TECHNIQUE

All measurement instrumentation was given an adequate warm-up period, and background and calibration readings were made whenever test measurements were made.

Simulant property measurements were made with Rotap machine (W. S. Tyler Co., Cleveland, Ohio) and standard Tyler sieves. Six sieves and a pan, nested with graduated mesh sizes, were thoroughly rotapped for 10 min to separate a 100-g sample into sieved fractions. Each fraction was weighed and its activity measured in the 4-pi ionization chamber (Fig. 2.8) to determine its specific activity (μc/g). The properties of each batch mixed are tabulated in Appendix B. Microscopic examination of the sieve fractions was also used to determine the size distribution as well as shape, and uniformity of the simulant batches.

Machine variables of forward speed, nozzle water pressure, and operational decontamination procedures were controlled for uniformity in all tests using activity. Forward speed was measured with a cab-mounted engine tachometer. Nozzle water pressure was measured by probes at each nozzle. The probes were manifolded to a pressure gauge in the cab where the pressure was manually controlled by the pump engine throttle. Duplication of operational decontamination procedures for each test was assured by operator pretest training and familiarization; and by external direction as the tests were being run.

Radiation measurements were made by a specially built mobile, shielded, gamma scintillation detector (Fig. 2.9). The radiation detection element was a NaI (Tl) scintillation crystal (1 in. diameter by 1 in. thick) that was coupled to a photomultiplier tube, all contained within a 6-in.-thick lead shield. A collimated aperature permitted entrance of radiation into the sensitive volume. The power supply, associated electronics, and printout system, as well as the shielded detector, were trailer mounted for mobility.

The effectiveness of the decontamination procedure was determined by comparing radiation measurements before and after each event.

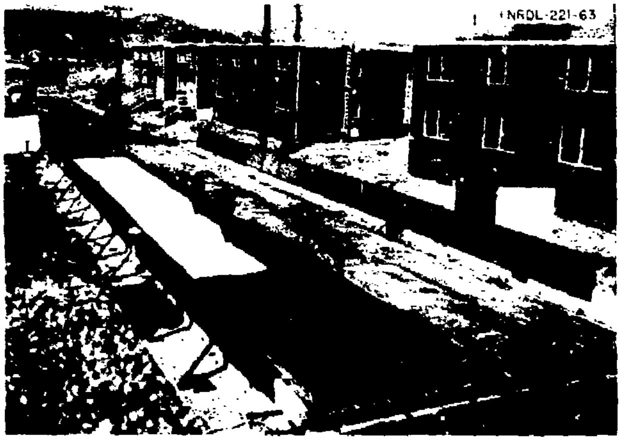

Fig. 2.7 Dispersal of Synthetic Fallout on Test Area by Hand-pulled Garden Spreader.

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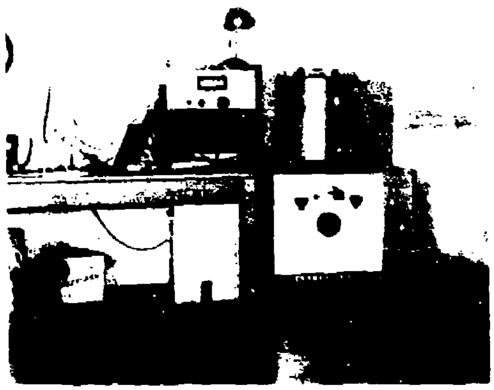

Fig. 2.8 4-pi Ionization Chamber

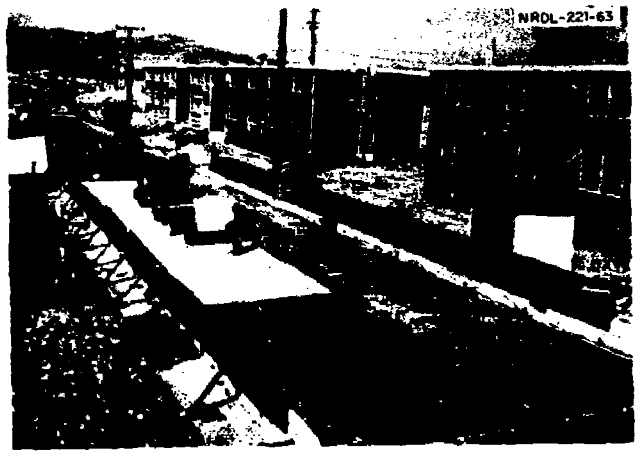

Fig. 2.9 Measuring Radiation Intensity of Synthetic Fallout with Scintillation Counter and Hand-held Radiac.

Reliability in the measurements made with the shielded detector was provided for by recording a series of two 1-minute counts in the following sequence:

a. Count a Co^{60} radiation standard, to determine the overall response of the instrument.

b. Count a sample from the synthetic fallout simulant batch to check simulant decay.

c. Count at each of the monitoring stations on the test area to collect data.

d. Repeat steps a and b as a further check on instrument response and decay.

The above four-step sequence was carried out for each test to measure the background, initial mass, and mass remaining after successive flushing passes. Time of day was recorded for each pair of counts to facilitate decay correction.

Hand-held portable radiacs, ANPDR-39 (T1B), were used as a check on the mobile shielded detector and for general monitoring purposes, such as controlling radiation dosage to personnel during preparation and dispersal of the simulant.

The 4-pi ionization chamber was used to assay the gross and sieved samples of the fallout simulant. It also followed the radioactive decay of each simulant batch as a check on radionuclide purity.

2.6 TEST PROCEDURE

Each of the tests with radioactive fallout simulant was conducted on a concrete or asphalt surface at initial mass level, particle size range, forward speed, and operational sequence required by the test conditions as follows:

a. Radiation background measurements were made as described in Section 2.5.

b. Synthetic fallout material of the desired particle size range and mass level was dispersed over an area 15.5 x 90 ft, as described in Section 2.4.

c. Initial mass level radiation measurement were made as described in Section 2.5.

d. One flushing cycle of the entire test area was made, consisting of 3 passes (as shown in Fig. 2.10) and described as follows:

1. First pass at crown of half-contaminated street, using both front nozzles at 40 psi to flush contaminant forward and toward the gutter.

2. Second pass alongside the gutter using 3 nozzles (Fig. 2.11), front nozzles at 35 psi and right rear nozzle at 60 psi, with a slight overlap of area cleaned on first pass.

3. Third pass in the gutter against the curb using two nozzles, right front at 35 psi and right rear at 60 psi, to flush material into catch basin or beyond test area.

4. All material flushed beyond test area was washed by fire-hose to catch basins and sumps, so that it would not contribute to radiation readings on test area. Contaminant was flushed from side boards into drain ditches as shown in Fig. 2.12, using left rear nozzle.

e. Radiation measurements were made as in Section 2.5.

f. Second flushing cycle was completed as in (d).

g. Final radiation was measured as in Section 2.5.

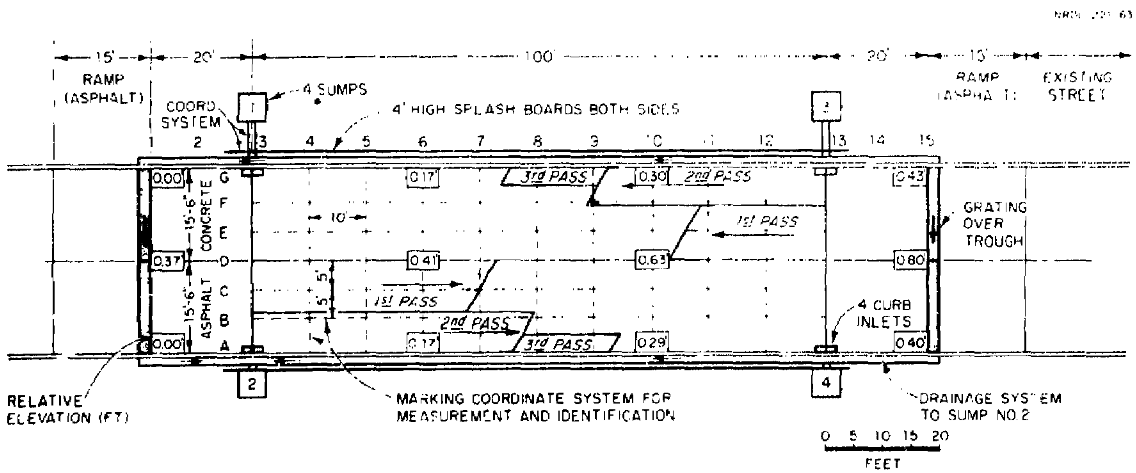

Fig. 2.10 Plan of Test Area Showing Contaminant Control Features and Flusher Pass Sequence.

Fig. 2.11 Second Flushing Pass at Curb Using Three Nozzles.

Fig. 2.12 Flushing Contaminant From Side Splash Boards into Drain Ditch Before Taking Radiation Reading on Test Surface.

CHAPTER 3

RESULTS AND DISCUSSION

The variation of effort that can be applied by a motorized flusher is infinite, within the limits of the ranges of the machine parameters of forward speed, water pressure, nozzle orientation, and of the operational procedures of nozzle usage and coverage of the area to be decontaminated. All the machine parameters and operational procedures were determined and held constant for the tests as described in Section 2.2 because of the limited scope of this test series. Under these test conditions distinct levels of effort were applied to the surface as defined by integral numbers of three-pass flushing cycles (Section 2.2) over the test area.

Effort is defined as being inversely proportional to the forward speed (or directly proportional to the time spent covering a given area). The relationship can be represented mathematically as

$$E = \frac{K}{S}$$

where E = effort in equipment-min/10^4 ft^2
S = forward speed in ft/min
and K is the proportionality factor.

In Reference 7 (the sweeper report), relative effort, RE, is defined as the ratio of actual effort E to a standard effort, which is shown to be equivalent to the expression

$$RE = \frac{1200}{S} \qquad (3.1)$$

where 1200 is an arbitrary speed selected to give RE values greater than unity. Using this relationship the work described here can be more easily compared with that of other tests - for instance, sweeper results in Reference 7*.

*Such a comparison is shown in Section 3.6.

The test condition prescribed a constant flusher speed of 6 mph or 528 ft/min. Therefore,

$$\text{RE (flusher)} = \frac{1200}{528} = 2.27$$

As long as the forward speed is held constant, 2.27 will be the RE for a complete coverage of the test area. For two coverages the RE will equal 2 x 2.27 = 4.54.

It was explained earlier in Section 2.6 that one coverage required a three pass flushing cycle. With a pass width of 9 ft (total frontal width of flushing pattern for 3 nozzles), the single pass rate would be 9 x 528 = 4752 ft^2/min. However, the test strip is 15.5 ft wide and three passes are required for complete coverage. Therefore an average pass width is 15.5/3 or 5.2 ft, and the average flushing rate is only 5.2 x 528 or 2746 ft^2/min.

Relative effort RE, then, is a function of speed only. It indicates neither the actual cleaning rate nor the absolute effort required. These two quantities are dependent upon the configuration of the area cleaned and upon the build-up of material which requires successive flushing passes to clear the remaining area. In addition, any allowances made for turn-around losses, tank-filling and post-flushing of redeposited material for ultimate disposal will further reduce the above rate estimates.

Using test conditions with fixed machine parameters, identical procedures were used to conduct 22 tests. The results of these tests are summarized in Table 3.1. The fallout environments simulated are given in terms of particle size and initial mass level; two surfaces, asphalt and concrete were used; and residual mass levels were computed from radiation readings as described in Appendix C. Corrected radiation measurements for all tests are given in Table C.1.

3.1 COMPARISON OF TESTS

The test results in Table 3.1 can be used for graphical presentation of data or to verify previously developed equations for the performance of wet decontamination methods. Using relative efforts as defined in Eq. 3.1 and corresponding residual mass levels determined from radiation measurements, Figs. 3.1 through 3.21 were plotted in three groups to show the effects of particle size, mass loading, and surface roughness on decontamination effectiveness.

TABLE 3.1

Residual Mass Levels (g/ft^2) Attained by Flusher for Various Fallout Conditions

	Cycle*	Residual Mass (g/ft^2) — Particle Size (µ)										
		44-88µ		88-177µ			177-350µ				350-700µ	
		Initial Mass Level g/ft^2										
		20	100	20	100	600	20**		100**		20	1.00
Asphalt	1	0.56	0.70	0.75	1.09	65.74	0.20	0.21	1.71	0.74	0.15	3.70
	2	0.42	0.32	0.48	0.66	2.20	0.03	0.11	0.00	0.20	0.055	0.26
Concrete	1	0.31	1.17	0.23	1.74	32.61	0.74	0.11	1.10	0.70	0.082	1.22
	2	0.27	1.09	0.22	0.80	1.76	0.21	0.088	0.23	0.24	0.057	0.14

* One cycle equals a three-pass flushing operation.
**For the 177-350µ particle size range duplicate tests were conducted.

Figs. 3.1-3.4

Comparisons of Effects of Particle Size on the Decontamination Performance of a Conventional Motorized Street Flusher, Using Test Procedures Described in Section 2.6.

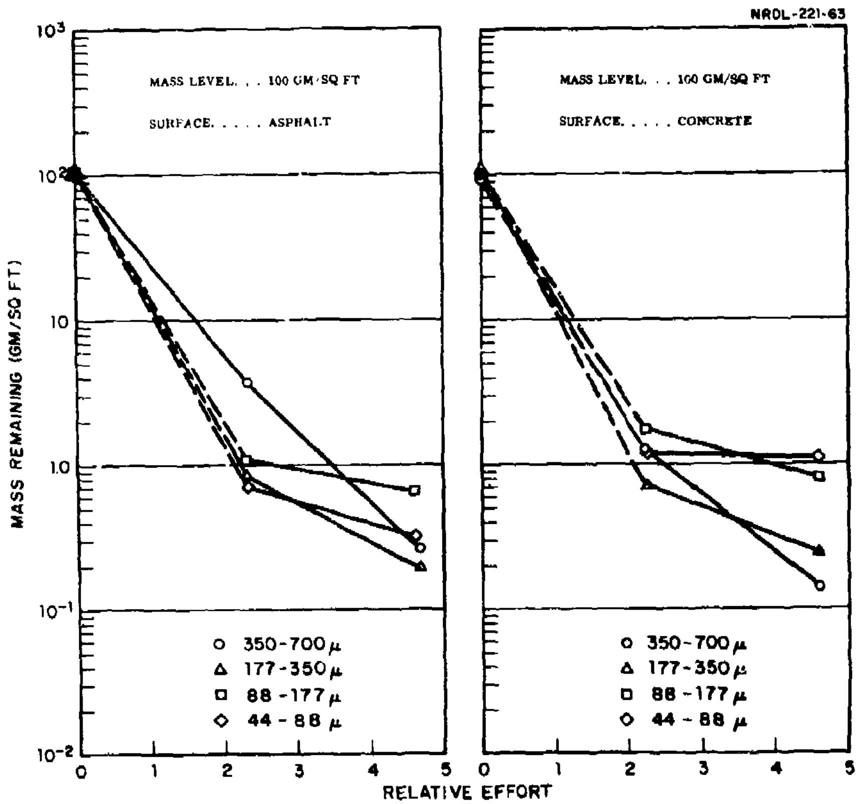
NRDL-221-63
MASS LEVEL. . . 100 GM/SQ FT
SURFACE. . . . . ASPHALT
MASS LEVEL. . . 100 GM/SQ FT
SURFACE. . . . . CONCRETE
MASS REMAINING (GM/SQ FT)
RELATIVE EFFORT
○ 350-700 μ
△ 177-350 μ
□ 88-177 μ
◇ 44-88 μ

Fig. 3.1

Fig. 3.2

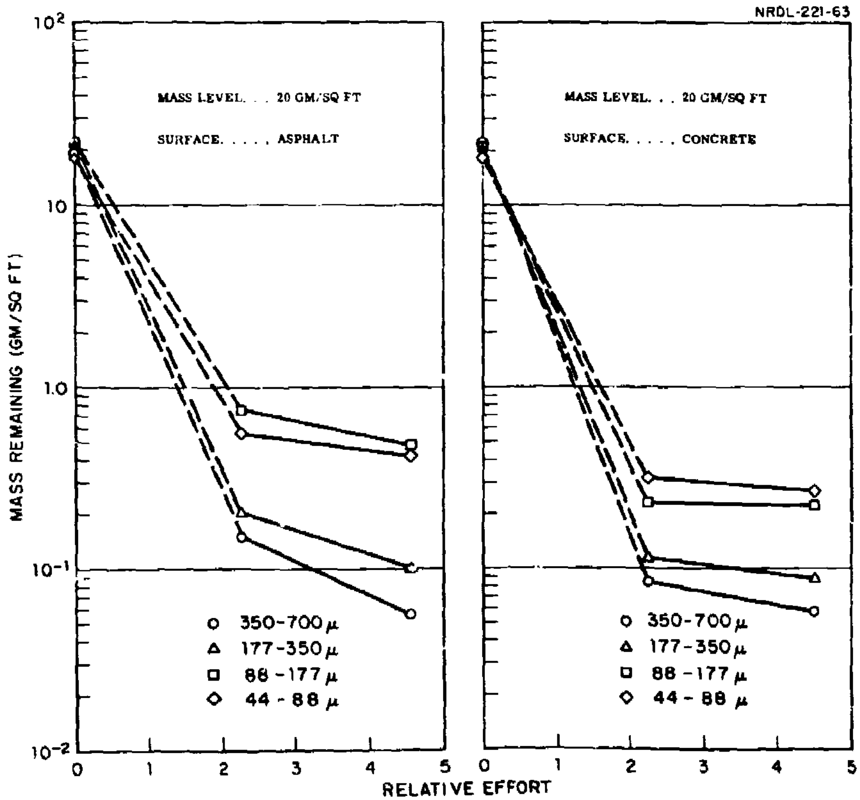
NRDL-221-63
MASS LEVEL. . . 20 GM/SQ FT
SURFACE. . . . . ASPHALT
MASS LEVEL. . . 20 GM/SQ FT
SURFACE. . . . . CONCRETE
MASS REMAINING (GM/SQ FT)
RELATIVE EFFORT
○ 350-700 μ
△ 177-350 μ
□ 88-177 μ
◇ 44-88 μ

Fig. 3.3

Fig. 3.4

Figs. 3.5-3.12

Comparisons of Effects of Initial Mass Levels on the Decontamination Performance of a Conventional Motorized Street Flusher, Using Test Procedures Described in Section 2.6.

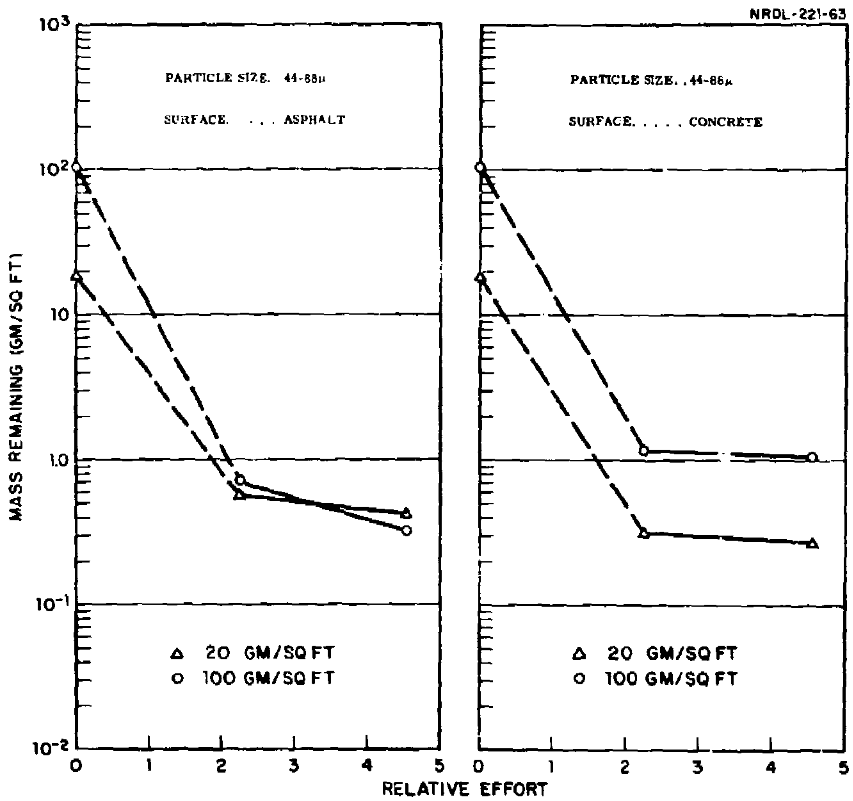
NRDL-221-63
PARTICLE SIZE. 44-88μ
SURFACE. . . . ASPHALT
PARTICLE SIZE. . 44-88μ
SURFACE. . . . . CONCRETE
MASS REMAINING (GM/SQ FT)
RELATIVE EFFORT
△ 20 GM/SQ FT
○ 100 GM/SQ FT
△ 20 GM/SQ FT
○ 100 GM/SQ FT

Fig. 3.5 Fig. 3.6

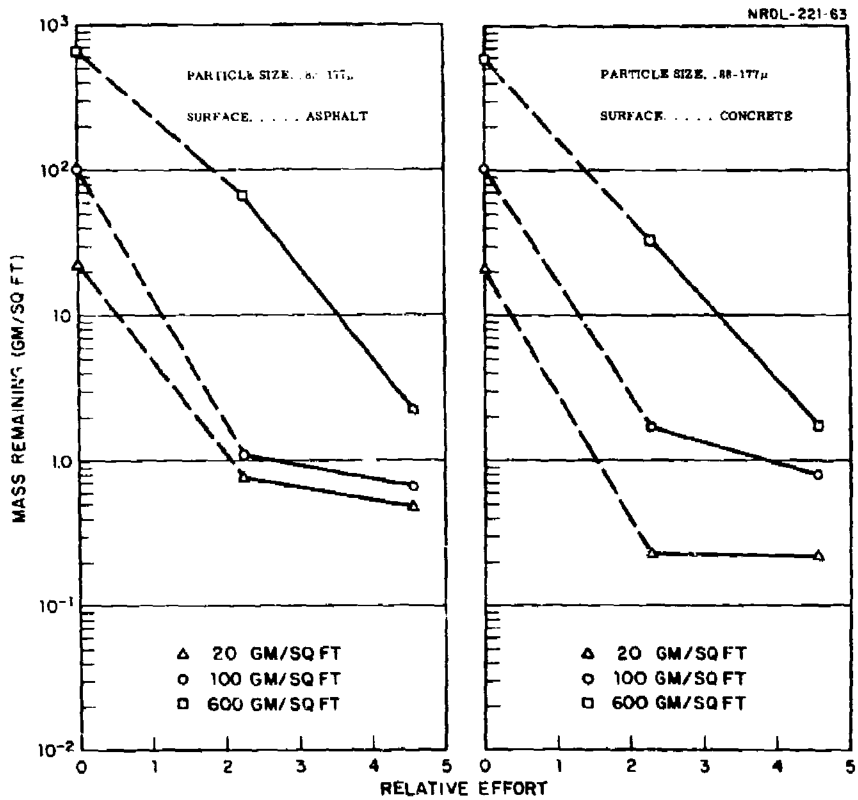
NRDL-221-63
PARTICLE SIZE. .88-177μ
SURFACE. . . . . ASPHALT
SURFACE. . . . . CONCRETE
MASS REMAINING (GM/SQ FT)
RELATIVE EFFORT
20 GM/SQ FT
100 GM/SQ FT
600 GM/SQ FT

Fig. 3.7

Fig. 3.8

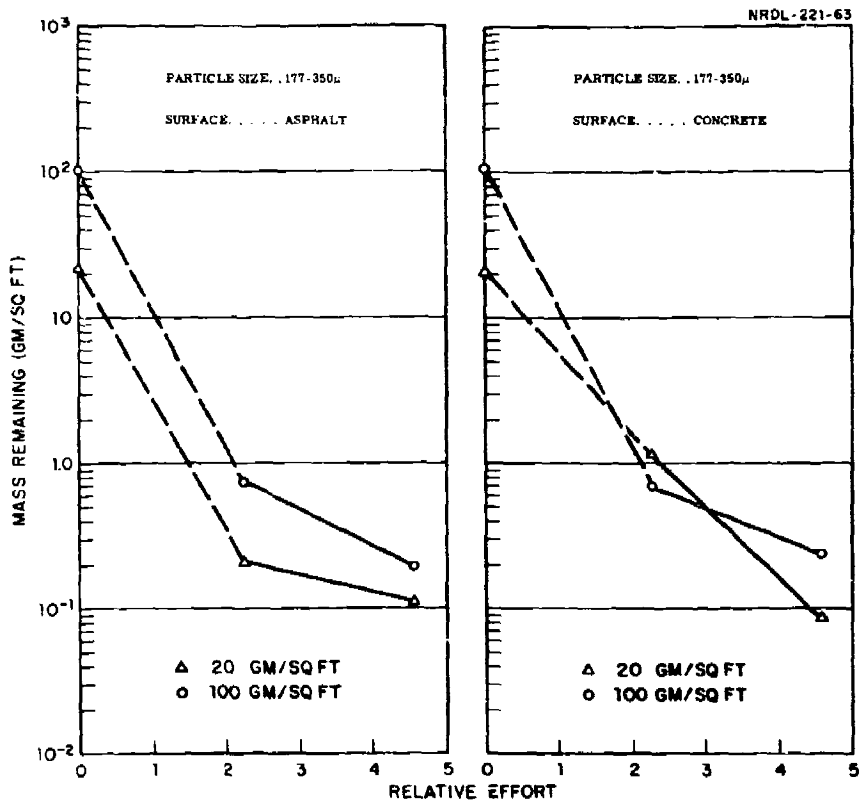

Fig. 3.9

Fig. 3.10

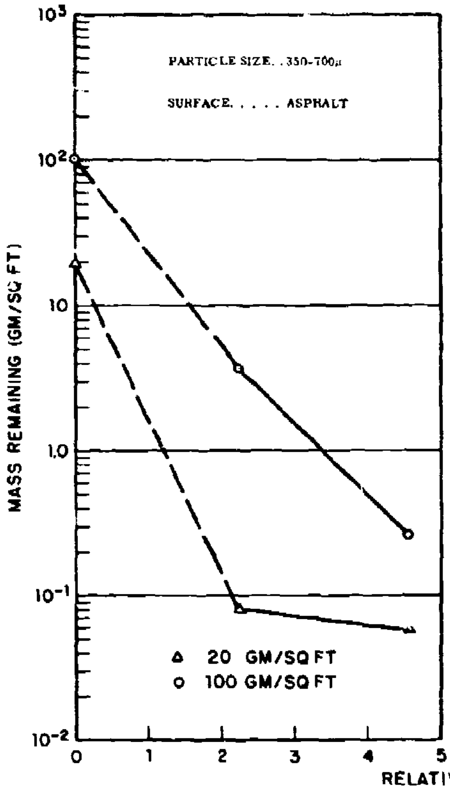

Fig. 3.11

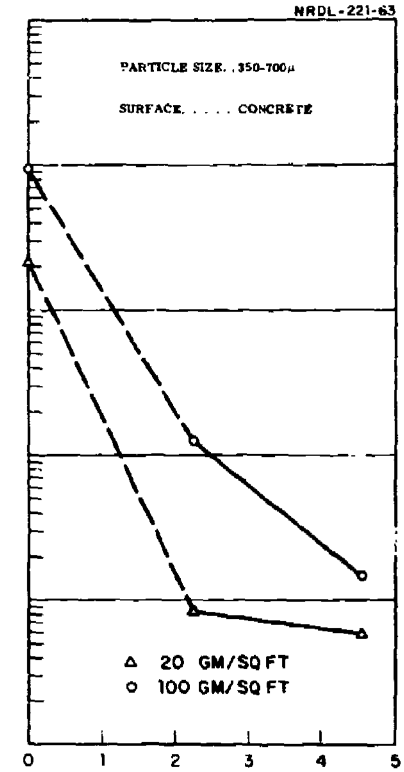

Fig. 3.12

Figs. 3.13-3.21

Comparisons of the Effects of Surface Roughness on the Decontamination Performance of a Conventional Motorized Street Flusher, Using Test Procedures Described in Section 2.6.

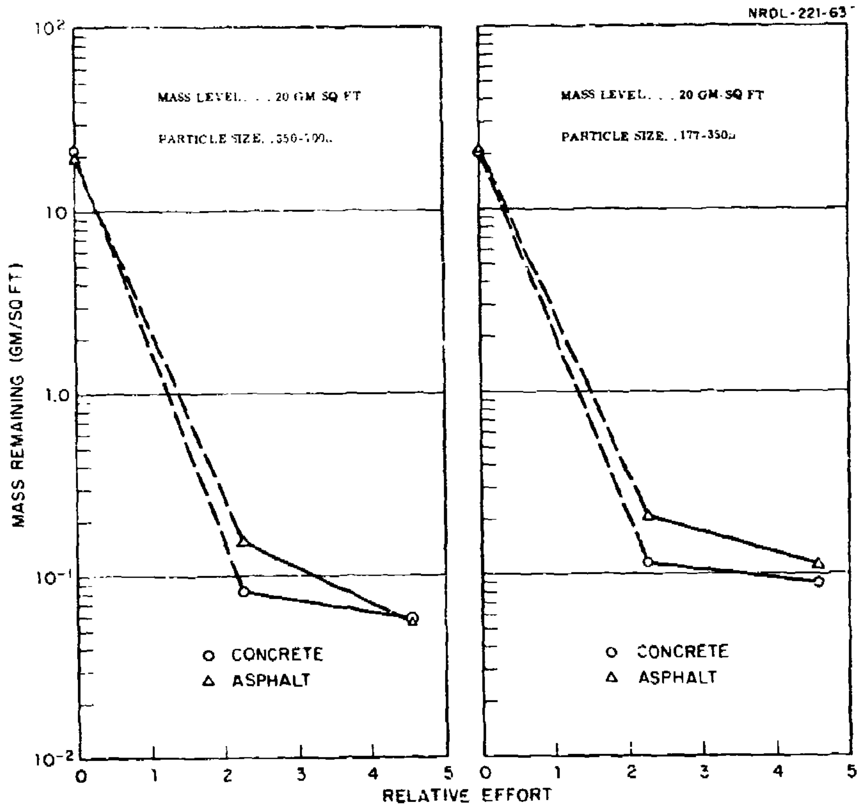

Fig. 3.13

Fig. 3.14

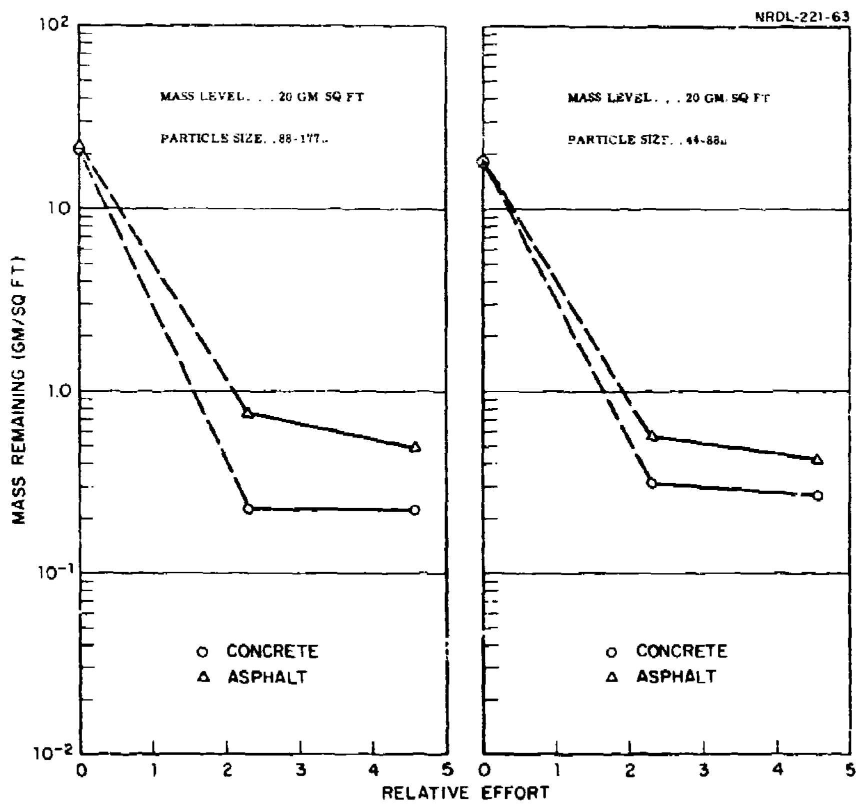

Fig. 3.15

Fig. 3.16

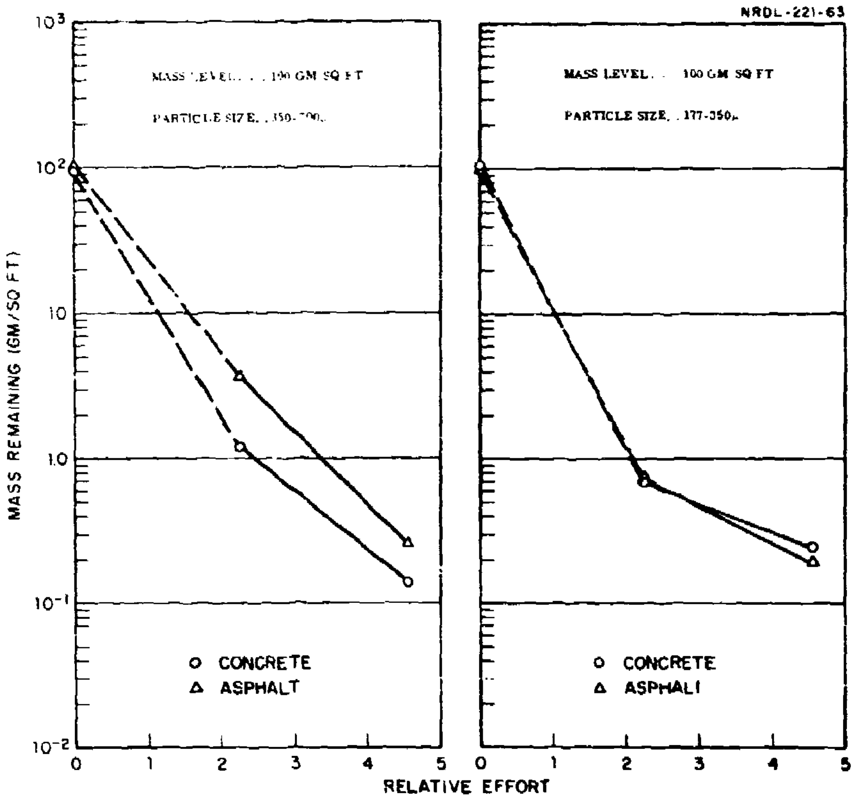

Fig. 3.17

Fig. 3.18

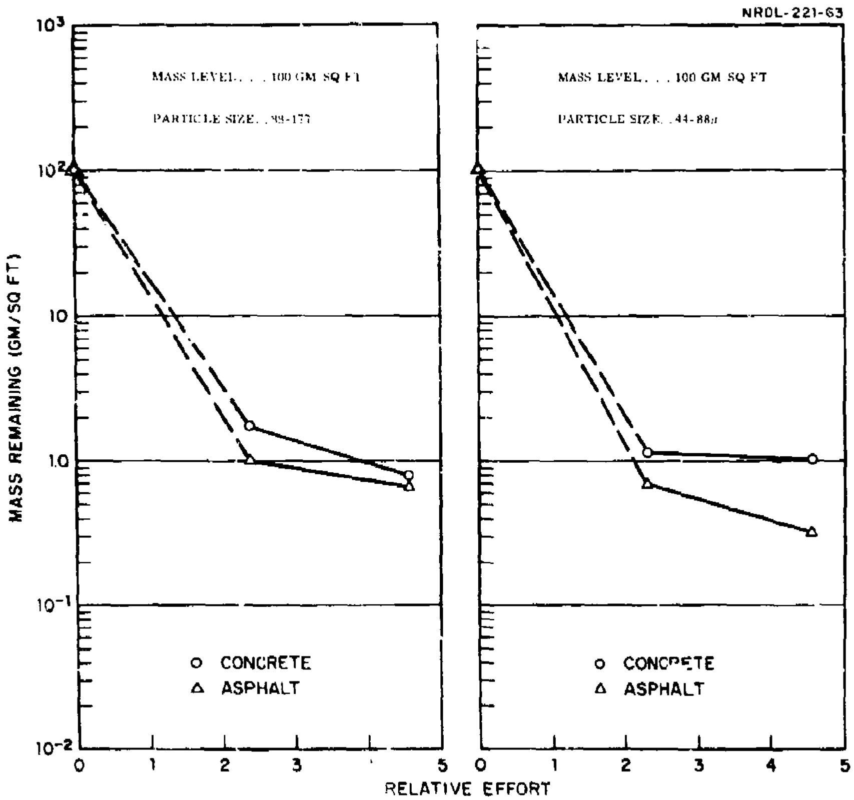

Fig. 3.19 Fig. 3.20

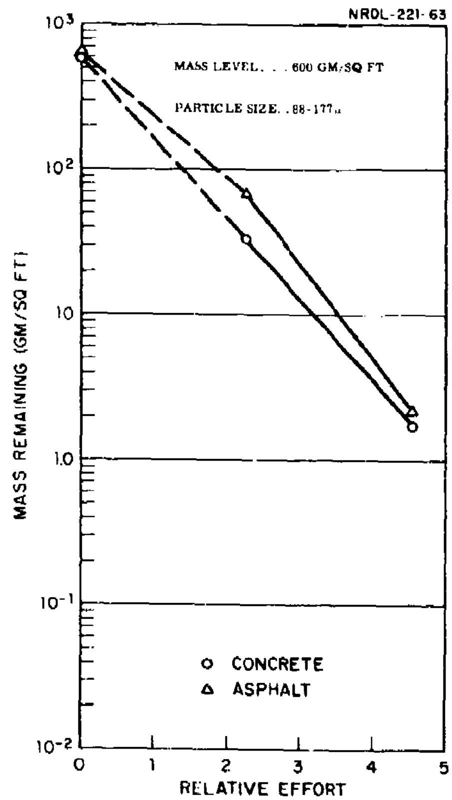
NRDL-221-63
MASS LEVEL. . . 600 GM/SQ FT
PARTICLE SIZE. . 88-177μ
MASS REMAINING (GM/SQ FT)
10³
10²
10
1.0
10⁻¹
10⁻²
O CONCRETE
Δ ASPHALT
0
1
2
3
4
5
RELATIVE EFFORT

Fig. 3.21

Only two data points appear for each test representing the residual mass after the 1st and 2nd cleaning cycles (each cleaning cycle representing three passes) so the shape of a smooth curve which fits the data could not be drawn. All conclusions drawn from these curves are for limited data from specific test conditions.

3.2 EFFECTS OF PARTICLE SIZE, MASS LEVELS AND SURFACE TYPE

Particle Size effects on decontamination are shown in Figs. 3.1-3.4. In all tests conducted the smallest particles were more difficult to remove than the largest particles. In Fig. 3.1 and 3.3 for asphalt surfaces, an inversion in the order of particle size vs. residual mass is seen: the 44-88μ particle size shows a lower residual mass than the 88-177μ particle size and the 177-350μ particle sizes (Fig. 3.1) shows a lower residual mass than the 350-700μ particle size. Although the removal effectiveness indicates inconsistencies due to flusher steering errors in the experimental results, the results as a whole shows small particles to be more difficult to remove than large particles at the same effort expenditure.

High initial mass levels consistently showed a greater residual mass level than lower mass levels after the same effort expenditure. Figures 3.5-3.11 show the effects of initial mass on the decontamination effectiveness of conventional motorized flushing. In addition to the problem of moving a higher mass per unit area, the build-up of material flushed to adjacent areas further compounds the mass removal problem, as described in Section 3.5 and discussed further in Section 3.6.

Surface type effects on decontamination effectiveness were not as conclusive as expected, due to the deterioration of the concrete surface prior to and during the evaluation studies using radioactive simulant. The concrete test surface had deep cracks at the expansion joints, and several rough spots were formed due to disintegration of the concrete. However, of the 9 tests conducted to allow comparison of surface type vs. effort, 5 showed that concrete was less difficult to clean than asphalt. One test showed about the same difficulty, and three tests showed asphalt to be less difficult to clean than concrete. The last three results were no doubt due to the contaminant retained in the large expansion joint cracks. An example of this effect can be seen in Fig. 3.20. Note the residual mass 1.2 g/ft^2 remaining after the first pass and the 1.02 g/ft^2 remaining after the second pass. The flatness of the curve indicates that a large amount of effort would be required to reach the same residual mass as attained on the asphalt surface.

It should be emphasized that although general conclusions may be drawn on particle size, mass level, and surface type effects, they are the results from only one set of flusher adjustments.

3.3 WATER CONSUMPTION

The water consumption rate was 0.14 gal/ft^2 for each complete 3-pass cleaning cycle used in the flusher evaluation tests. This rate is similar to that of previous tests mentioned in Section 1.1 but applies only to the present test procedure. Other flushing procedures would require different consumption rates. An ideal flushing situation, where a single, 9-ft-wide path at higher speed (12 mph) is adequate, could have a water consumption rate of 0.032 gal/ft^2 using the two front nozzles. At the other extreme, a heavy mass loading on a large area would require a slower speed, multiple passes, and manual firehose clean-up after flushing. This extreme situation might be handled more expeditiously by a different or combination method, with flushing being the final clean-up of low residual mass achieved by another method such as sweeping.

3.4 EXPERIMENTAL ERROR

The results of duplicate tests shown in Table 3.1 vary by as much as a factor of 7. The differences are due almost entirely to variations in operating techniques (mainly directional control of the flusher truck) from test to test. The accuracy of direct measurements was $\pm$ 3 % for forward speed, $\pm$ 5 % for initial mass level, and $\pm$ 15 % for the radiation measurements used to determine residual mass level, thus these items did not contribute significantly to observed differences.

Some error was introduced into the residual mass level measurements for several reasons: (a) As shown in Fig. B.1 (Appendix B) the specific activity increased for smaller particles within a given particle size range. (b) However flushing selectively removed the larger particles more readily than the smaller and more active particles within a particle size range. Therefore, calculations of residual mass M based on radiation measurements will be conservative (too high).

For instance, residual mass is calculated from the expression

$$M = M_o \frac{R}{I_o}$$

where M_o = initial mass loading, g/ft^2
R = residual radiation reading, mr/hr
I_o = initial radiation reading, mr/hr

For the above-noted reasons, the residual radiation reading R will be high, since a disproportionate amount of small but more radioactive particles will be left after flushing. Therefore the estimates of mass will also be high.

Specific activity varied by a factor of 3 within each size range of fallout simulant used, but the relatively narrow size ranges (a factor of 2) permitted a valid determination of the effect of particle size on flushing effectiveness.

Transfer of activity from the simulant to the test surfaces by leaching or ion exchange contributed less than 0.1 % error to the measurements and was therefore ignored as a source of experimental error.

Form line cracks in the concrete surface retained some simulant and produced some localized high radiation readings. These radiation readings were deleted from calculations as indicated in Appendix C. However, the frequency of random surface cracks at monitoring stations was not sufficient to create a serious bias in the data when these readings were averaged with the rest of the stations to obtain a representative residual reading for the whole test surface.

3.5 FLUSHING THEORY

Previous wet decontamination evaluation studies derived the following equation:

$$M = M^* + (M_o - M^*)\ e^{-3K_o E^{1/3}} \tag{3.2}$$

where M is the residual mass (g/ft^2) after finite effort expenditure E.
M^* is the residual mass (g/ft^2) at an infinite effort level
M_o is the initial mass level (g/ft^2)
K_o is the proportionality constant expressing removal rate
E is the effort expended (equipment min/10^4 ft^2)
$e^{-3K_oE^{1/3}}$ is the fraction of removable mass remaining after expending the effort, E.

Equation 3.2 was solved for each test using data values of M, M_o, and E, and making successive approximations for M* and K_o for a fit through the data points on an M vs E plot (see Fig. 3.22 for such a plot). The existence of only two data points and a limited number of tests for each surface-method combination made it impossible to evaluate other previously derived equations[3] relating initial mass to residual mass at infinite effort for a given decontamination method.

Of 22 test runs, 13 listed in Table 3.2 provided data which could be fitted to equation 3.2. The variation of ultimate residual mass attainable (M*) and rate of mass removal (K_o) are consistent with results presented graphically in Section 3.1. The M* values indicate small particles are more difficult to remove than large particles, concrete surfaces have lower residual mass than asphalt for the same test condition, and higher initial mass levels require more effort to achieve the same residual mass level. The K_o values show faster removal rate for concrete surfaces and lower mass levels. No clear cut trend of removal rates with respect to particle size was indicated.

3.6 COMPARISON OF MOTORIZED STREET FLUSHING AND MOTORIZED STREET SWEEPING

Figure 3.22 compares the relative performance of street flushing with street sweeping methods. Test results were taken for like conditions of mass loading, particle size and surface type. Each curve was plotted according to its respective cleaning equation.

From the distinct separation between the curves, it appears that flushing is the superior method. However, comparing these two performances in this manner assumes both methods carry out their respective cleaning task to a similar state of completeness. This occurs only in one particular situation, the reclaiming of open roadways where flushing does not create a disposal problem.

It is more likely that sweepers and flushers will be operating on streets bordered by curbs or on extensive areas such as parking lots and industrial aprons. Under these conditions flushers usually cannot do a complete job of reclamation. As the work progresses the flusher will eventually reach the point where it can no longer push aside the mass build-up of fallout material. A secondary method is then required to get rid of this accumulation of spoil.

TABLE 3.2

Fit of Equation 3.2 to Test Data

Test Conditions		Equation 3.2 Parameters	
Test No.	Initial Mass M_o (g/ft^2)	$-3K_o$ $\left(\frac{10^4 ft^2}{equip\ min}\right)^{1/3}$	M^* (g/ft^2)
C-20-W	21.5	4.25	0.051
A-20-W	19.5	3.24	0.019
C-20-X	20.7	4.31	0.083
A-20-X	21.8	3.29	0.073
C-100-X	107.4	3.34	0.076
C-20-Y	21.0	4.85	0.218
A-20-Y	22.1	2.56	0.328
C-100-Y	102.2	2.79	0.353
A-100-Y	101.9	3.34	0.507
A-20-Z	18.4	2.91	0.356
C-100-Z	102.5	4.52	1.074
C-20-Z	18.6	3.81	0.259
A-100-A	103.5	3.45	0.192

Notes:

Test Code is: surface type - nominal initial mass - particle size

A = Asphalt X = 177-350μ
C = Concrete Y = 88-177μ
W = 350-700μ Z = 44-88 μ

Equation 3.2: $M = M^* + (M_o - M^*)\ e^{-3K_o E^{1/3}}$

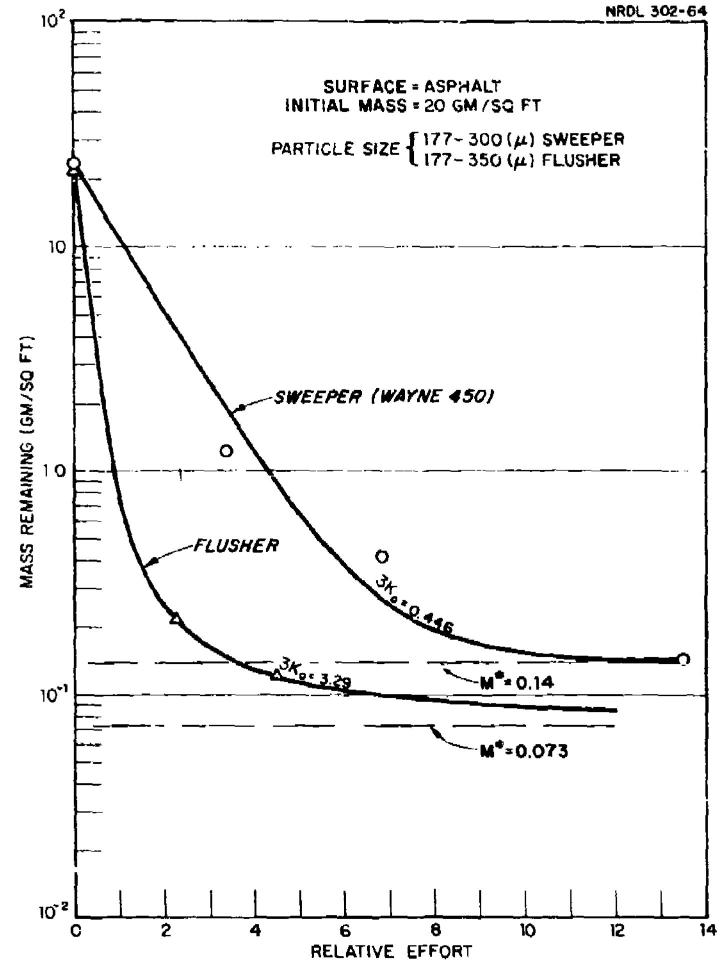

Fig. 3.22 Comparison of Cleaning Performances of Motorized Street Sweeping and Motorized Street Flushing.

For this more general situation, a comparison of the above curves is misleading, since the flusher curve does not take into account the additional effort required to complete the reclamation of a given area. Thus, comparisons of these or similar pairs of method performance curves must not be made without consideration of the inherent differences between methods.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Previously developed theoretical decontamination equations fit data for a majority of the tests. With the exception of some of the factors related to removal rate (K_o), good agreement was found between the equation and the data. The conclusions suggested by the test results are presented below.

The systematic procedure for adjustment and orientation of the nozzles described in Section 2.2 can be applied beneficially to any motorized flusher to achieve optimum decontamination performance.

Under the test conditions used, mass level had the greatest influence on flushing effectiveness. Particle size had the next greatest effect and surface type had the least effect. Some variations in uniformity of distribution were noted on the concrete surface when form lines accumulated the material. Under comparable test conditions, high initial mass levels were harder to remove than low initial mass levels, small particles were harder to remove than large particles, and rough asphalt surfaces retained a greater residual mass than smooth concrete surfaces.

Motorized flushing is an effective decontamination procedure for recovery of extensive areas if the following problems are recognized and overcome: (a) a possible shortage of water; (b) an insufficient number of flushers; (c) the accumulation of flushed material due to high initial mass level and/or the accelerated build-up of flushed material in an extensive area having a low initial mass level; and (d) the safe handling and ultimate disposal of the flushed material.

The consumption rates attained in the present evaluation tests are ideal from the standpoint of water economy in that only consumption on the test area was measured. Higher consumption rates under less carefully planned and executed procedures could easily increase the rate by a factor of two or three, making the procedure impractical if the water supply were marginal.

It is readily apparent that careful planning is required for each flusher situation to insure an integrated recovery system of optimum performance. The complexity of handling and disposing of the flushed material varies from an ideal situation where a single pass is sufficient to the complex case where multiple passes are required. In the simpler cases, as on a narrow paved road with ditches on each side, a single pass cleans the surface and disposes of the contaminant into the ditch where its effects are partially shielded out. Wide city streets demand multiple pass flushing cycles to overcome mass build-up and to move the accumulated material from along curbs and gutters to collection points.

4.2 RECOMMENDATIONS

Since the present series of tests represents a very limited effort, it is recommended that further tests be run to explore other combinations of flusher adjustments and operating techniques. The first additional tests should be made to determine some of the effects of forward speed and whether it must be accounted for in some of the theoretical equations.

Further work should be done to determine whether a combination method (such as sweeping followed by flushing) might show some merit. Additional procedural variations of street flushing to suit various area configurations should be investigated. Since the present test did not verify the cleaning equation satisfactorily and the current data is not sufficient to establish new equations, further investigations should be made to verify previous equations, or new equations should be developed.

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6. D. E. Clark, Jr., W. C. Cobbin, "Some Relationships Among Particle Size, Mass Level, and Radiation Intensity of Fallout From a Land Surface Nuclear Detonation," U. S. Naval Radiological Defense Laboratory Technical Report USNRDL-TR-639, March 1963.

7. D. E. Clark, Jr., W. C. Cobbin, "Removal Effectiveness of Simulated Dry Fallout From Paved Areas by Motorized and Vacuumized Street Sweepers," U. S. Naval Radiological Defense Laboratory Technical Report USNRDL-TR-746, 8 August 1963.

APPENDIX A

PRELIMINARY TESTS

To determine motorized flusher adjustments that would give optimum performance, a series of 70 preliminary small-scale tests was run. The tests were conducted on the concrete half of the special test area using non-radioactive synthetic fallout of 177-350 μ particle size range. The following flushing procedure was used for all preliminary tests: (1) The flusher speed was 6 mph. (2) One front nozzle was used at 40 psi. (3) The area width selected was such that the one nozzle used would provide complete coverage of the area with one pass. (4) Each pass was made at the prescribed speed and the water jet was activated only within the designated length of a specific test area. (5) A weight material balance technique was used to obtain quantitative results. Although the weighing technique proved to be unsatisfactory for the main series of the tests, it served well for the determination of optimum settings and usage of the flusher nozzles. Significant results of a few tests are discussed here.

One series of tests was run to determine the upper limit of initial mass level that could be removed by the flusher. Table A.1 shows results for six tests which indicate that the limiting mass level for the test conditions used is somewhere between 456 and 612 g/ft^2. Test #14 at the 612 g/ft^2 initial mass level presents a serious buildup and drop-out of the flushed material. Build-up and drop-out of flushed material occurs when the mass loading and distance flushed is such that the accumulated material can no longer be moved by the force of water. The actual build-up of material begins when flushing begins. As the flushing progresses the mass build-up of material eventually exceeds the ability of the water jet to transport it any further. At this point, drop out occurs and the material is redeposited on the surface.

The increasing efficiency of removal (grams/gal) with a maximum at the 4th pass is explained by the materials not being completely wetted as the water or jet passed over. The speed, mass level, and water flow rate were such that the fallout simulant formed wet balls that rolled across the dry sand below. The most efficient flushing was achieved at lower mass loadings because the fallout simulant was thoroughly wetted before the main impact of the nozzle jet.

TABLE A.1

Effect of Initial Mass Level on Flushing Efficiency

Test:	#15	#19	#16	#17	#52	#14
Initial Mass: (g/ft^2)	199	193	308	312	456	612
Pass	Grams removed/gal water					
1	2503	3106	3260	2972	9240	884
2	2018	1222	3361	3755		834
3						1374
4						1877
5						785
6						319

Test #52 was used to measure the loss of material with distance flushed. Except for a small residual mass, the 450 g/ft^2 mass loading was completely cleaned with one pass of the flusher. The amount of material collected and weighed from areas beyond the 10-foot-long test area gave some indication of the ability of the flusher to transport material beyond the immediate contaminated area. For the single pass over the area the amount removed as a function of distance may be expressed in terms of the percent drop out beyond a given distance as follows:

Distance Flushed (ft)	Drop-out (%)
5	7.2
10	28.4
15	51.6
20	68.7
25	78.0
30	86.7
Beyond	95.4

Due to the limited accuracy of weighing the drop-out to obtain a material balance, 4.6 % could not be accounted for. These results indicate an operational problem associated with flushing fallout, since additonal work may be required to dispose of the flushed material.

APPENDIX B

PHYSICAL AND RADIOLOGICAL PROPERTIES OF FALLOUT SIMULANT

Four batches of fallout simulant were used in the flusher evaluation studies. Each batch was analyzed to determine its physical and radiological properties. The results of these measurements are presented in Tables B.1 through B.4.

The simulants' nominal particle size ranges were determined as described in Section 2.5. A slight increase in particle size was observed after the sodium silicate sealant was added to physically fix the radionuclide to the sand; however these small increases in the particle size range did not affect the test conditions appreciably. The specific activity (μc/g) of each radioactive-tagged batch's sieve fractions was measured in the 4π ionization chamber (Fig. 2.8) to determine the uniformity of tagging.

The intent of the radionuclide-tagging process in the production of fallout simulant was to obtain a constant specific activity (μc/g) for all particles in a nominal particle size range. If ideal tagging is achieved, a direct relationship between radiation intensity and residual mass is obtained even after a decontamination method has been applied.

The tagging process used consists of spraying a solution of radioactive La^{140} onto the surface of the bulk carrier material. If uniform coverage is achieved the amount (in μc) of radioactivity on a particle will be proportional to the surface area. The radioactivity can be related to volume or mass (for uniform material density) for spherical particles of diameter d as follows:

$$\frac{\text{Activity}}{\text{Mass}} = \left(K' \frac{\text{Surface}}{\text{Volume}} \right) = \left(K' \frac{\pi d^2}{\pi d^3/6} \right) = K\ (1/d) \qquad \text{(B.1)}$$

where K is a proportionality constant between specific activity (μc/g) and the reciprocal of the particle diameter (1/d). If this idealized relationship prevailed in practice, a plot of specific activity vs. the reciprocal of particle diameter would be a straight line of slope K. However, the above idealized activity-mass proportionality to particle diameter is altered in the actual tagging process because particles are non-spherical or agglomerated.

TABLE B.1

Physical and Radiological Properties of Fallout Simulant Batch No. 1 Having a Nominal Particle Size Range 350 μ to 700 μ

Sieve Size		Weight Analysis (%)		Radioactivity Analysis (%)
U.S. Mesh	Microns	Raw Material	Tagged Material	
25	701	0.3	0.3	0.2
30	589	1.3	0.9	0.7
35	495	14.2	12.4	10.9
40	417	33.6	30.2	27.7
45	350	48.1	51.4	52.4
50	295	2.1	3.1	4.9
Pan	-295	0.4	1.7	3.2
Totals		100.00	100.00	100.00

Date Batch Mixed	8/28/61
Specific Activity (μc/g) at Mixing Time	14.4

TABLE B.2

Physical and Radiological Properties of Fallout Simulant Batch No. 2 Having a Nominal Particle Size Range 177 μ to 350 μ

Sieve Size		Weight Analysis (%)		Radioactivity Analysis (%)
U.S. Mesh	Microns	Raw Material	Tagged Material	
40	417	0.4	0.6	0.4
45	350	1.5	2.6	1.3
50	295	8.1	9.3	5.3
60	246	22.7	25.7	16.4
80	177	41.9	45.1	40.3
100	149	17.8	12.0	22.8
Pan	-149	7.6	4.7	13.5
Totals		100.00	100.00	100.00
Date Batch Mixed		9/6/61		
Specific Activity (μc/g) at Mixing Time		6.9		

TABLE B.3

Physical and Radiological Properties of Fallout Simulant Batch No. 3 Having a Nominal Particle Size Range 88 μ to 177 μ

Sieve Size		Weight Analysis (%)		Radioactivity Analysis (%)
U.S. Mesh	Microns	Raw Material	Tagged Material	
70	208	0.9	0.8	0.9
80	177	1.3	1.3	1.8
100	149	10.6	28.6	25.7
120	124	25.6	25.8	21.1
170	88	52.8	40.7	42.2
200	74	7.9	2.6	7.3
Pan	-74	0.9	0.2	1.0
Totals		100.00	100.00	100.00

Date Batch Mixed 9/27/61

Specific Activity (μc/g) 9.7
at Mixing Time

TABLE B.4

Physical and Radiological Properties of Fallout Simulant Batch No. 4 Having a Nominal Particle Size Range 44 μ to 88 μ

Sieve Size		Weight Analysis (%)		Radioactivity Analysis (%)
U.S. Mesh	Microns	Raw Material	Tagged Material	
150	104	2.6	7.6	10.2
170	88	11.0	15.7	16.2
200	74	31.2	29.3	25.6
230	62	28.2	25.7	23.8
270	53	11.7	8.7	8.8
325	44	11.8	9.9	11.3
Pan	-44	3.5	3.0	4.1
Totals		100.00	100.00	100.00
Date Batch Mixed		10/6/61		
Specific Activity (μc/g) at Mixing Time		14.7		

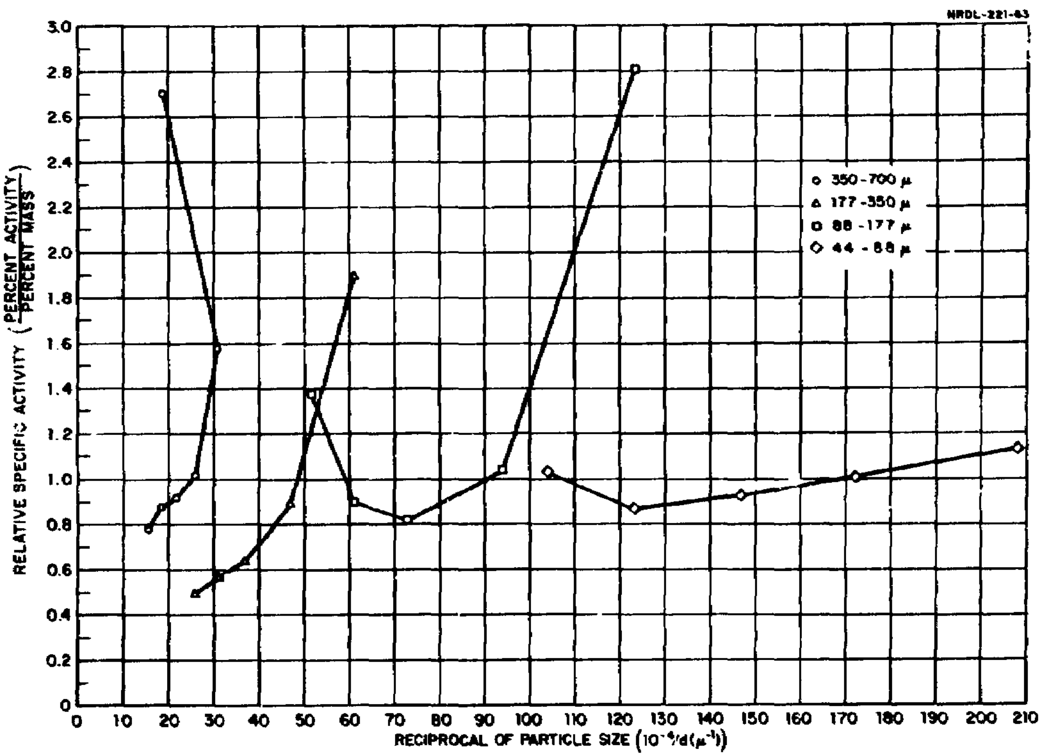

Fig. B.1 Specific Activity of Simulant Sieve Fractions

In Fig. 3.1 relative specific activity (% activity/% mass) for the sieve fractions of each batch has been plotted against (1/d), the latter being determined from the sieve fraction mid size given in microns. The straightness of the lines formed by segments connecting the data points of each batch indicates how well Eq. B.1 applies, and provides a comparison of the various batches.

APPENDIX C

CORRECTED RAW TEST DATA

Table C.1 shows corrected counts/minute for each monitoring station for all tests where radiation measurements were taken. The concrete test surface coordinate stations were B 4-B11 and C4-C11 inclusive; asphalt test surface stations were E5-E12 and F5-F12 inclusive as designated on Fig. 2.10. Two one-minute counts were averaged, and corrected for instrument response and decay. Tests with the same zero time (same simulant batch) may be compared directly, while tests from different batches must be corrected for different specific activities given in Tables B.1 through B.4.

Conversion of radiation measurements to mass was achieved as follows:

(a) Counts at 16 stations were averaged to determine one count for entire test surface for typical initial, 1st pass and 2nd pass counts.

(b) $\text{Residual } (g/ft^2) = \dfrac{(\text{initial } g/ft^2)(\text{residual count})}{\text{initial count}}$

The nozzle pressures used in the tables of Appendix C are as follows:

Pass	Nozzle (psi) Left Front	Nozzle (psi) Right Front	Nozzle (psi) Right Rear
1st	40	40	0
2nd	35	35	60
3rd	0	35	60

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-20-W
DATE 9/20/61
INITIAL MASS 21.5 (g/ft²)
ZERO TIME 9/28/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 350-700 (μ)
SPEED 6 mi (hr)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

210306	216629	ND	222364	235261	246909	269988	ND
202635	ND	ND	207484	220342	226414	223360	ND

CYCLE NO. 1 (C/m)

1427	1074	ND	589	999	456	679	ND
1304	ND	ND	650	1166	338	737	ND

CYCLE NO. 2 (C/m)

585	729	ND	355	982	309	457	ND
490	ND	ND	606	993	452	633	ND

TEST NO A-20-W
DATE 9/30-31/61
INITIAL MASS 19.53 (g/ft²)
ZERO TIME 9/29/1200

SURFACE TYPE ASPHALT
SPEED 6 mi (hr)
PARTICLE SIZE 350-700 (μ)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

208573	215555	181667	180956	190316	226741	226697	202043
196332	237638	204800	238629	194880	190811	194605	205265

CYCLE NO. 1 (C/m)

641	977	1182	1098	1515	1186	1277	1768
5138	1112	612	714	1661	2472	1565	2424

CYCLE NO. 2 (C/m)

397	788	673	478	662	830	841	1247
230	0	338	154	542	710	824	808

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-20-X
DATE 9/8/61

INITIAL MASS 20.67 (g/ft²)

ZERO TIME 9/6/1200

SURFACE TYPE CONCRETE

PARTICLE SIZE 177-350 (μ)
SPEED 6 mi (hr)
AREA SIZE 1396 (Ft²)

INITIAL READINGS (C/m)

299316	294759	ND	290195	291706	295946	293291	ND
291573	ND	ND	269929	265784	254394	273111	ND

CYCLE NO 1 (C/m)

1752	1696	ND	1437	2460	1027	949	ND
1509	ND	ND	1281	2419	1398	1099	ND

CYCLE NO 2 (C/m)

1091	943	ND	1031	2019	769	761	ND
1061	ND	ND	1152	2192	1230	953	ND

TEST NO A-20-X
DATE 9/11/61

INITIAL MASS 21.91 (g/ft²)
ZERO TIME 9/6/1200

SURFACE TYPE ASPHALT

SPEED 6 mi (hr)
PARTICLE SIZE 177-350 (μ)
AREA SIZE 1396 (Ft²)

INITIAL READINGS (C/m)

327283	345612	323675	329463	345514	359428	338200	329939
372522	405662	397355	428140	391402	403169	415229	397891

CYCLE NO 1

2339	5079	3799	2406	4797	5210	4729	5920
2532	3222	2500	1809	2523	3237	2102	2953

CYCLE NO 2

1671	3036	2650	2256	2320	2609	2907	3065
776	1363	1578	828	1044	1578	1107	1376

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-20-Y
DATE 10/21/61

SURFACE TYPE CONCRETE

PARTICLE SIZE 88-177 (μ)
SPEED 6 mi (hr)
AREA SIZE 1395 (Ft²)

INITIAL MASS 20.99 (g/Ft²)
ZERO TIME 9/27/1200

INITIAL READINGS (C/m)

193079	196259	ND	170024	162472	166456	154408	ND
129116	ND	ND	142727	139801	137311	144606	ND

CYCLE NO 1 (C/m)

1204	1345	ND	1440	1651	736	975	ND
1615	ND	ND	2117	2544	2874	2196	ND

CYCLE NO 2 (C/m)

1280	1386	ND	1356	1368	1072	850	ND
1636	ND	ND	1683	2457	3205	2091	ND

TEST NO A-20-Y
DATE 10/2-3/61

SURFACE TYPE ASPHALT

SPEED 6 mi (hr)
PARTICLE SIZE 88-177 (μ)
AREA SIZE 1395 (Ft²)

INITIAL MASS 22.13 (g/Ft²)
ZERO TIME 9/27/1200

INITIAL READINGS (C/m)

159816	159316	161172	162891	172562	176997	161987	191196
185793	190723	193410	173266	190066	194900	171423	186091

CYCLE NO 1 (C/m)

4027	4821	4891	6217	6179	6477	4969	7661
6477	6590	2726	4484	9073	6604	3345	10760

CYCLE NO 2 (C/m)

3468	4494	4434	4516	5177	5384	4276	5761
2941	3669	2121	2690	3797	2696	2191	3893

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-20-Z
DATE 10/12/61
INITIAL MASS 18.55 (G/Ft²)
ZERO TIME 10/6/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 44-88 (μ)
SPEED 6 mi (hr)
AREA SIZE 1396 (Ft²)

INITIAL READINGS (C/m)

164969 Δ	164262 Δ	ND Δ	178519 Δ	169073 Δ	171762 Δ	165710 Δ	ND Δ
153819 Δ	ND Δ	ND Δ	143871 Δ	136875 Δ	135922 Δ	125545 Δ	ND Δ

CYCLE NO. 1 (C/m)

2260 Δ	2133 Δ	ND Δ	2065 Δ	2830 Δ	1552 Δ	2220 Δ	ND Δ
2600 Δ	ND Δ	ND Δ	3082 Δ	3751 Δ	4304 Δ	3119 Δ	ND Δ

CYCLE NO. 2 (C/m)

2191 Δ	2315 Δ	ND Δ	1734 Δ	2154 Δ	1503 Δ	1649 Δ	ND Δ
2185 Δ	ND Δ	ND Δ	2225 Δ	3066 Δ	3609 Δ	2275 Δ	ND Δ

TEST NO A-20-Z
DATE 10/11/61
INITIAL MASS 18.39 (G/Ft²)
ZERO TIME 10/6/1200

SURFACE TYPE ASPHALT
SPEED 6 mi (hr)
PARTICLE SIZE 44-88 (μ)
AREA SIZE 1396 (Ft²)

INITIAL READINGS (C/m)

132052 Δ	130914 Δ	105114 Δ	90720 Δ	127164 Δ	130663 Δ	119843 Δ	134741 Δ
107467 Δ	128367 Δ	109029 Δ	110952 Δ	116516 Δ	134868 Δ	124913 Δ	144015 Δ

CYCLE NO. 1 (C/m)

1395 Δ	3130 Δ	2979 Δ	1670 Δ	3210 Δ	5426 Δ	4507 Δ	6198 Δ
2246 Δ	4148 Δ	5587 Δ	3947 Δ	3631 Δ	4471 Δ	2972 Δ	3519 Δ

CYCLE NO. 2 (C/m)

731 Δ	1951 Δ	2095 Δ	1169 Δ	2748 Δ	4349 Δ	3327 Δ	5059 Δ
1648 Δ	2866 Δ	3814 Δ	3658 Δ	3251 Δ	3290 Δ	2513 Δ	2296 Δ

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-100-W
DATE 8/31-9-1/61
INITIAL MASS 94.22 (g/ft²)
ZERO TIME 8/28/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 350-700 (μ)
SPEED 6 mi(hr)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

1006764	943609	ND	883490	890250	901924	845711	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
956652	[illegible]	ND	1055679	1059701	1016033	1021445	ND
Δ		Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO 1 ( )

36615	78	ND	3898	8423	1953	2486	ND
Δ		Δ	Δ	Δ	Δ	Δ	Δ
5423	ND	ND	4021	9047	5101	2739	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO 2 (C/m)

1562	1035	ND	0	2614	200	406	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
3328	ND	ND	2053	3316	805	761	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TEST NO A-100-W
DATE 9/5/61
INITIAL MASS 102.52 (g/ft²)
ZERO TIME 8/28/1200

SURFACE TYPE ASPHALT
SPEED 6 mi(hr)
PARTICLE SIZE 350-700 (μ)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

1320439	1294825	1391747	1324400	1269280	1301001	1272021	1299157
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
989703	940045	1146524	1122093	1113751	1177659	1193629	1072402
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO 1 (C/m)

64381	37592	65549	54399	71129	51596	25945	17442
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
96836	37746	7027	7201	13496	4397	1991	0
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO 2 (C/m)

304	1421	1807	2236	2413	1954	2253	3728
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
0	2949	4091	4300	4313	5569	3277	3230
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-100-X
DATE 9/11-12/61

INITIAL MASS 107.40
ZERO TIME 9/6/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 177-350 (μ)
SPEED 6 mi (hr.)
AREA SIZE 1395 (Ft²)

INITIAL READINGS (C/m)

1904973	1969911	ND	2133595	2065382	2204029	2175424	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
2046669	ND	ND	2147839	2103446	2211161	2050381	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 1 (C/m)

31677	35679	ND	11896	15114	4860	5896	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
13700	ND	ND	8396	11342	6206	6042	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 2 (C/m)

3321	4151	ND	5468	8279	2569	2624	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
4955	ND	ND	4760	7007	4369	4636	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TEST NO A-100-X
DATE 9/12-14/61

INITIAL MASS 101.54 (g/Ft²)
ZERO TIME 9/6/1200

SURFACE TYPE ASPHALT
SPEED 6 mi (hr.)
PARTICLE SIZE 177-350 (μ)
AREA SIZE 1395 (Ft²)

INITIAL READINGS (C/m)

2957991	2535738	2589393	2616173	2635229	2962705	2892805	2917094
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
2708195	2763094	2846729	2610460	2597984	2845545	2577266	2456698
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 1 (C/m)

7085	12649	11712	9992	16646	16915	32534	73365
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
5998	13340	9864	7814	26946	29677	11937	23410
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 2 (C/m)

4465	5578	6271	4979	5954	5898	6241	4620
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
2203	4490	4541	3634	4966	4661	4210	5098
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-100-Y
DATE 10/3-4/61

SURFACE TYPE CONCRETE

PARTICLE SIZE 88-177(μ)

INITIAL MASS 102.19 (g Ft²)

SPEED 6 mi (hr)

ZERO TIME 9/27/1200

AREA SIZE 1395(Ft²)

INITIAL READINGS (C/m)

800592 Δ	821515 Δ	ND Δ	874783 Δ	860892 Δ	969913 Δ	928739 Δ	ND Δ
914172 Δ	ND Δ	ND Δ	937621 Δ	942711 Δ	941296 Δ	960814 Δ	ND Δ

CYCLE NO. 1 (C/m)

6296 Δ	43490 Δ	ND Δ	28937 Δ	15985 Δ	3682 Δ	6485 Δ	ND Δ
12513 Δ	ND Δ	ND Δ	11968 Δ	12901 Δ	14606 Δ	11539 Δ	ND Δ

CYCLE NO. 2 (C/m)

5077 Δ	8488 Δ	ND Δ	5973 Δ	5567 Δ	2803 Δ	8304 Δ	ND Δ
5090 Δ	ND Δ	ND Δ	8058 Δ	10927 Δ	12185 Δ	10179 Δ	ND Δ

TEST NO A-100-Y
DATE 10/4-5/61

SURFACE TYPE ASPHALT

SPEED 6 mi (hr)

INITIAL MASS 101.87 (g/Ft²)

PARTICLE SIZE 88-177 (μ)

ZERO TIME 9/27/1200

AREA SIZE 1395 (Ft²)

INITIAL READINGS (C/m)

991913 Δ	1025231 Δ	1053412 Δ	1046224 Δ	1049430 Δ	1099293 Δ	1082725 Δ	1090640 Δ
1095808 Δ	1116717 Δ	1136859 Δ	1053939 Δ	1082464 Δ	1064923 Δ	973258 Δ	957412 Δ

CYCLE NO. 1 (C/m)

7833 Δ	9230 Δ	8920 Δ	7903 Δ	9304 Δ	11372 Δ	14535 Δ	18218 Δ
9728 Δ	20379 Δ	6029 Δ	5007 Δ	9431 Δ	13154 Δ	10708 Δ	19130 Δ

CYCLE NO. 2 (C/m)

6502 Δ	8161 Δ	7771 Δ	6996 Δ	9551 Δ	8684 Δ	9727 Δ	12462 Δ
5275 Δ	5793 Δ	3956 Δ	3699 Δ	3933 Δ	6261 Δ	5689 Δ	5696 Δ

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-600-Y
DATE 10/9/61
INITIAL MASS 590.11 (G/FT²)
ZERO TIME 9/27/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 88-177(μ)
SPEED 6 mi.(hr)
AREA SIZE 180 (FT²)

INITIAL READINGS (C/m)

10219965	10023578	ND	10355403	10650802	10679269	11165712	ND

CYCLE NO. 1 (C/m)

251534	667108	ND	660313	671134	799457	497715	ND

CYCLE NO. 2 (C/m)

31312	35269	ND	32223	37553	30402	24997	ND

TEST NO A-600-Y
DATE 10/10/61
INITIAL MASS 638.44 (G/FT²)
ZERO TIME 9/27/1200

SURFACE TYPE ASPHALT
SPEED 6 mi (hr)
PARTICLE SIZE 88-177 (μ)
AREA SIZE 160 (FT²)

INITIAL READINGS (C/m)

	16195792	16512643	16227672	16312629	15912895	15094117	15213754

CYCLE NO. 1 (C/m)

	613089	1572582	1790197	2487638	3042429	94427	1774082

CYCLE NO. 2 (C/m)

	62714	74840	66168	75038	21112	2179	0

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-100-Z
DATE 10/13/61
INITIAL MASS 102.42 (g/ft²)
ZERO TIME 10/6/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 44-88 (μ)
SPEED 6 mi (hr)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

782081 Δ	861866 Δ	ND Δ	839026 Δ	842477 Δ	865676 Δ	984948 Δ	ND Δ
820629 Δ	ND Δ	ND Δ	862968 Δ	860750 Δ	944313 Δ	934495 Δ	ND Δ

CYCLE NO. 1 (C/m)

10191 Δ	7101 Δ	ND Δ	3696 Δ	4478 Δ	2991 Δ	3462 Δ	ND Δ
4496 Δ	ND Δ	ND Δ	4225 Δ	5802 Δ	7441 Δ	5127 Δ	ND Δ

CYCLE NO. 2 (C/m)

3290 Δ	4703 Δ	ND Δ	4025 Δ	0 Δ	0 Δ	2991 Δ	ND Δ
3524 Δ	ND Δ	ND Δ	4786 Δ	5292 Δ	6105 Δ	4794 Δ	ND Δ

TEST NO A-100-Z
DATE 10/13/61
INITIAL MASS 103.49 (g/ft²)
ZERO TIME 10/6/1200

SURFACE TYPE ASPHALT
SPEED 6 mi (hr)
PARTICLE SIZE 44-88 (μ)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

942791 Δ	990923 Δ	993225 Δ	982319 Δ	993666 Δ	1011956 Δ	975520 Δ	951960 Δ
741772 Δ	804033 Δ	916237 Δ	896116 Δ	845138 Δ	1040699 Δ	853460 Δ	890551 Δ

CYCLE NO. 1 (C/m)

2438 Δ	0 Δ	3422 Δ	5396 Δ	5346 Δ	6254 Δ	8241 Δ	13551 Δ
5755 Δ	6168 Δ	5097 Δ	2598 Δ	5254 Δ	7752 Δ	4942 Δ	8166 Δ

CYCLE NO. 2 (C/m)

2233 Δ	3236 Δ	2934 Δ	2067 Δ	3516 Δ	3077 Δ	5446 Δ	6814 Δ
1207 Δ	1995 Δ	3578 Δ	926 Δ	1932 Δ	1836 Δ	1318 Δ	2409 Δ

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-20-X (A) dup
DATE 8/11/61
INITIAL MASS 22.7 (g/ft²)
ZERO TIME 8/7/1200

SURFACE TYPE Concrete
PARTICLE SIZE 177-350(μ)
SPEED 6 mi.(hr)
AREA SIZE 1395(ft²)

INITIAL READINGS (C/m)

403875	431658	ND	462624	474205	499977	508058	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
598015	ND	ND	558422	565188	552258	536533	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 1 (C/m)

4356	3056	ND	1076	1612	186	0	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
117216	ND	ND	51934	0	3808	0	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 2 (C/m)

4310	3306	ND	3119	7921	3338	4961	ND
Δ	Δ	Δ	Δ		Δ	Δ	Δ
551.	ND	ND	3470	9177	1564	2385	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TEST NO A-20-X (B) dup
DATE 8/15/61
INITIAL MASS 20.8 (g/ft²)
ZERO TIME 8/7/1200

SURFACE TYPE ASPHALT
SPEED 6 mi. (hr.)
PARTICLE SIZE 177-350(μ)
AREA SIZE 1395 (ft²)

INITIAL READINGS (C/m)

593753	685569	658235	624319	610088	658165	584429	688484
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
562715	590230	672456	561343	579731	596382	562860	585700
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 1 (C/m)

17112	3589	1992	2392	3690	6485	4469	10120
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
11940	5676	4296	3455	4580	17129	5681	6937
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 2 (C/m)

1681	2509	801	1383	3409	3180	451	2461
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
100	1359	1331	856	551	1697	0	0
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TABLE C-1

CORRECTED RAW DATA FOR MOTORIZED FLUSHING

TEST NO C-100-X-(C) dup.
DATE 8/17/60
INITIAL MASS 101.9 (g. Ft^2)
ZERO TIME 8/7/1200

SURFACE TYPE CONCRETE
PARTICLE SIZE 177-350 (μ)
SPEED 6 mi (hr)
AREA SIZE 1395 (Ft^2)

INITIAL READINGS (C/m)

2910589	2912092	ND	2911081	2757438	2663442	2602443	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
3310747	ND	ND	2996713	2978785	3292497	3292489	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 1 (C/m)

69772	84043	ND	17126	10289	6989	3704	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
118511	ND	ND	11048	18466	7050	5143	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 2 (C/m)

6171	5209	ND	7156	8349	5010	2880	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
10754	ND	ND	7326	13615	4201	3689	ND
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

TEST NO A-100-X (D) dup
DATE 8/16/60
INITIAL MASS 108.7 (g. Ft^2)
ZERO TIME 8/7/1200

SURFACE TYPE ASPHALT
SPEED 6 mi (hr)
PARTICLE SIZE 177-350 (μ)
AREA SIZE 1395 (Ft^2)

INITIAL READINGS (C/M)

3498044	3541350	3592994	3760336	3747781	3761611	3729143	3732146
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
2939659	3022256	2957247	2811350	2821927	3245749	2663310	3078872
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 1 (C/M)

4227	12190	12209	13640	16034	18433	61119	378788
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
7930	25170	15052	14764	27598	142942	40960	116767
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

CYCLE NO. 2 (C/M)

2153	1763	4251	2343	0	0	0	4235
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
1090	2806	2353	1341	2714	2513	1470	0
Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

APPENDIX D

STREET FLUSHER SPECIFICATIONS

Truck: GMC Model M73
6-cylinder gasoline engine, 97 hp at 3450 RPM
6-10.00X20 12 ply tires - single at front; dual at rear
13,500 lb gross weight empty
28,500 lb gross wt w/2000 gal water

Tank: 2000 gal capacity, oval cross-section, steel, electrically welded, flat front head, internally braced w/baffle plates
18 in. diameter manhole w/gasket
overload indicator float
3 in. diameter overflow
2-1/2 diameter firehose filler w/coupling and swivel connection

Power Pump Unit: Mounted between tank and truck cab, with engine choke, ignition and starter switch in cab
Engine: Continental, 6-cylinder, gasoline, water cooled 86 hp at 3250 RPM
Pump: Centrifugal, 500 GPM at 40 psi

Nozzles: Standard bronze 2-piece horizontally split slot type 2-1/2 in. flushing nozzles - swivel, adjustable and hand locked in position or angle of spray.
The two at front used in tests - one at left rear used for cleanup of test area side splash boards.
Special water broom brass type scaled up to 1-1/2 in. size from 1 in. firehose type developed by W. L. Owen of NRDL for firehose decontamination studies.

Valves: 2 in. size individually controlled by lever - cable system from cab for any operating combination.

Piping: 2-1/2 in. diameter manifolded from pump outlet through valves to nozzles.

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The flusher nozzle orientation
(over)

1. Radioactive fallout.
2. Street cleaning apparatus.
3. Pavements.
4. Decontamination.
5. Cleaning.
6. Surface bursts.

I. Clark, D. E.
II. Cobbin, W. C.
III. Title.
IV.

UNCLASSIFIED

was adjusted for maximum decontamination effectiveness. This adjustment can be applied to any flusher to be used for similar purposes. Using a fixed set of flusher adjustments and constant-size test area, the effects of 4 particle size ranges, 3 mass levels, and 2 types of surfaces on removal effectiveness were determined.

The least effective removal by flushing (2.2 g/ft^2 residual mass) for a given expenditure of effort was obtained at high initial mass loadings (100 to 600 g/ft^2) on asphalt surface using small particles (44-88 μ and 88-177 μ). The best removal effectiveness by flushing (0.06 g/ft^2 residual mass) for the same expenditure of effort was obtained using low initial mass loading (20 g/ft^2) on concrete surface with 350 to 700 μ particle sizes.

A majority of the tests conducted were in agreement with previously developed theoretical equations describing decontamination in terms of residual mass as a function of expended effort.

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